Ex. 5 - Deliberative Process

[redacted]

Ex. 5 - Deliberative Process

[redacted]

ENFORCEMENT SENSITIVE - FOIA Exempt

Ex. 5 - Deliberative Process

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Ex. 5 - Deliberative Process

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Ex. 5 - Deliberative Process

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ENFORCEMENT SENSITIVE - FOIA Exempt

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Experimental Work to Verify the Basic Mechanism of Fume Formation

G. J. W. Kor and E. T. Turkdogan -- Steel Research

1. EXPLANATION OF THE BASIC MECHANISM OF FUME FORMATION

About 20 years ago, Turkdogan and co-workers studied the basic mechanism of iron-oxide fume formation by means of a series of well-controlled experiments. From this work it became clear that metal oxide fumes are formed by reaction of the metal vapor, which is always present over a bath of liquid metal, and the oxygen present in the gas phase. Fig. 1 shows schematically how this process takes place.

As shown in Fig. 1a, the metal vapor diffuses away from the metal surface while the oxygen in the gas phase diffuses toward the metal surface. At some short distance, δ, from the surface the metal vapor and the oxygen react to give finely divided iron-oxide particles in the form of a fog or mist. Because of the formation of the oxide, the partial pressures of iron vapor and oxygen are close to zero in the zone where the fog is formed (Fig. 1b). Therefore, the formation of iron oxide in the gas phase creates a sink to which iron vapor and oxygen diffuse counter current wise, as also shown in Fig. 1b.

For a given set of experimental conditions an increase in the oxygen content of the gas decreases the distance (δ) over which the metal vapor is diffusing. Hence, the rate of vaporization increases as shown schematically in Fig. 2b. Increasing the oxygen concentration still further will cause the supply of oxygen to the metal surface to exceed the supply of metal vapor, and the result is that the metal surface oxidizes, leading to cessation of vaporization, Fig. 2b.

A visual demonstration of this fume-formation phenomenon is provided by Fig. 3. These pictures were taken of levitated pure iron melts which were exposed to $He-O_2$ gas mixtures. As the concentration of oxygen in the gas mixture increases, the extent of fuming increases. The fourth picture from the left is for pure oxygen. In this case the metal surface is oxidized; therefore, there is little fuming. The last picture is for an iron melt containing 4 percent carbon, levitated in pure oxygen. Because of the reaction between the carbon and the oxygen, iron oxide cannot form on the metal surface; therefore, metal vaporizes at a fast rate forming iron-oxide fumes. The sparks of metal droplets caused by rapid CO evolution increases the surface area and causes even more intense fuming.

During furnace tapping and pouring of liquid steel or hot metal, there is no slag cover on the metal; therefore, fume formation is inevitable. However, on the basis of the mechanism just described, it is clear that fume formation can be drastically reduced by replacing air from the exposed surface of the liquid metal. Effective replacement of air (oxygen) above the exposed surface of the liquid metal is a prerequisite for all fume-suppression techniques.

2. LABORATORY-SCALE EXPERIMENTS TO VERIFY THE BASIC MECHANISM OF FUME FORMATION

To further verify the mechanism of fume formation from iron alloys (steel), particularly with respect to the role of manganese, it was decided to perform experiments in which the pouring of steel was simulated. In these experiments about 50 pounds of steel were melted in an induction furnace and subsequently poured into a crucible. The fumes emitted during tapping were drawn through a hood suspended over the crucible and collected on a glass wool filter which was analyzed for total iron and manganese after each experiment. Various shrouding gases, including steam, could be supplied during tapping.

The typical tap time for these experiments was about 1 minute, and this made it difficult to obtain reproducible results with respect to the total amount of material (iron and manganese) collected on the filter although every attempt was made to collect all the fumes emitted during a tap. To maintain fume generation for a period of about one hour, 500 pounds of steel were kept molten in an induction furnace. The metal surface was kept free from oxide by skimming repeatedly. Isokinetic samples were extracted from the hood-duct system suspended over the furnace.

In analyzing the results from these experiments, it has to be kept in mind that the melts used in both types of experiments were not pure liquid iron but liquid steel that contained, among other things, manganese as one of the important alloying elements. When extending the basic mechanism of fume formation, described before, to alloys of iron containing manganese, it has to be kept in mind that in addition to iron, the manganese will vaporize also. Because manganese is about 1000 times more volatile than iron at typical pouring temperatures, it is to be expected that a fume emitted by an iron-manganese alloy such as steel will be enriched in manganese. In other words, the ratio of manganese to iron in the fume will be higher than the manganese to iron ratio that follows from the bulk steel composition. In fact, by measuring the Mn/Fe ratio in the material emitted during a tap without a shroud and comparing that with the Mn/Fe ratio in the material emitted during tapping with a shroud, we can get an indication of the effectiveness of a particular shrouding method. The more effective a shrouding technique is in keeping oxygen away from the liquid steel surface the less fuming will occur and the closer will be the Mn/Fe ratio in the emitted material to that pertaining to the bulk composition of the steel.

This is shown in Fig. 4 in which the Mn/Fe ratios observed in the material collected during tapping of a 50-pound melt without a shroud (middle curve) are compared with the Mn/Fe ratios in the material collected during tapping with a steam shroud (lower curve). Also indicated in Fig. 4 is the Mn/Fe ratio in the collected material, if it were to consist entirely of particles that were formed via the fuming mechanism described earlier. The high Mn/Fe ratio is a result of the high volatility of manganese at these temperatures.

The reason that the "no shroud" data deviate from the calculated line is that the actually collected material consists of a mixture of "pure fume" particles having a Mn/Fe ratio close to theoretical and particles mechanically ejected from the steel melt having a Mn/Fe ratio of the particles emitted during tapping with a steam shroud are systematically lower, indicating that less "pure fume" was formed during tapping with a steam shroud. The Mn/Fe ratio in the particles collected for the 500-pound steel melts, generated over a period of one hour without a shroud, show good agreement with the data obtained during tapping of a 50-pound steel melt without a shroud (Fig. 4, middle curve).

These data do, therefore, indicate that shrouding with steam during tapping has a beneficial effect on the amount of fume emitted. This is also corroborated by the data obtained from the 500-pound experiments, summarized in the table.

Suppression	Amount Emitted, lb./hr.
None	0.090
None	0.080
None	0.090
Flame	0.037
Flame	0.045
Flame	0.045
Steam*	0.035

*Duration 16 minutes.

With the exception of the steam-suppressed test, all tests were run over a one-hour period.

It is seen that the emissions from suppressed heats are about half those of the nonsuppressed heats. Flame-suppressed tests were performed by burning a natural-gas flame over the surface of the liquid steel, thus consuming the oxygen and leading to less fuming.

3. THE ROLE OF STEAM-WATER SHROUDS IN SUPPRESSION OF FUMES

Already in the earliest plant trials using steam shrouding for fume suppression, it was found that a mixture of steam and water gave better results than dry steam only. In general, it can be said that gas shrouding using a shower-head arrangement over the ladle is in principle not fully effective in expelling all of the oxygen from the melt surface. This is because of the unavoidable entrainment of air (oxygen) into the gas shroud expanding over the ladle.

It was hypothesized that a steam-water mixture is more effective than a gas shroud in expelling air from the melt surface because the evaporating fine water droplets in close proximity to the melt surface are able to expell the air (oxygen) more effectively, thus leading to less fuming.

To test this hypothesis experimentally, a series of special experiments was undertaken. In these experiments, mixtures of argon and oxygen (up to 2% O_2) were jetted on the surface of 150 grams (∿50 ounces) of liquid iron-manganese melts (1% Mn) contained in an enclosed system such that the fumes could be trapped. In a parallel series of experiments water was injected as a fine spray together with the Ar-O_2 mixture. This was done to simulate steam-water shrouding. During each experiment the total amount of iron and manganese emitted per second per unit area of the melt was measured.

The results are summarized in Fig. 5 where the total amount of iron and manganese emitted is shown as a function of the amount of oxygen in the gas. The total amount emitted when no water is injected (upper curve) is about a factor of two to eight higher than the amount emitted when water is injected in the form of a fine spray (lower curve). These results, therefore, form strong support for the hypothesis that steam-water shrouds give better results in fume suppression because the evaporating water droplets in the vicinity of the liquid metal surface expel the oxygen more effectively, thus leading to less fume formation.

4. CONCLUSIONS

1. As indicated by the basic mechanism of fume formation, an effective fume-suppression method is that which can expel air most efficiently from the vicinity of the melt surface.

2. Gas shrouding with a shower-head arrangement is in principle not fully effective because of air entrainment in the expanding gas jet.

3. Steam-water mixtures are effective in suppressing fumes. The evaportating water droplets above the melt surface effectively displace air (oxygen) in the atmosphere above the melt.

4. Shrouding with burning natural gas has been found to be an effective method to keep oxygen away from the melt surface by virtue of the fact that the oxygen is consumed in the burning process.

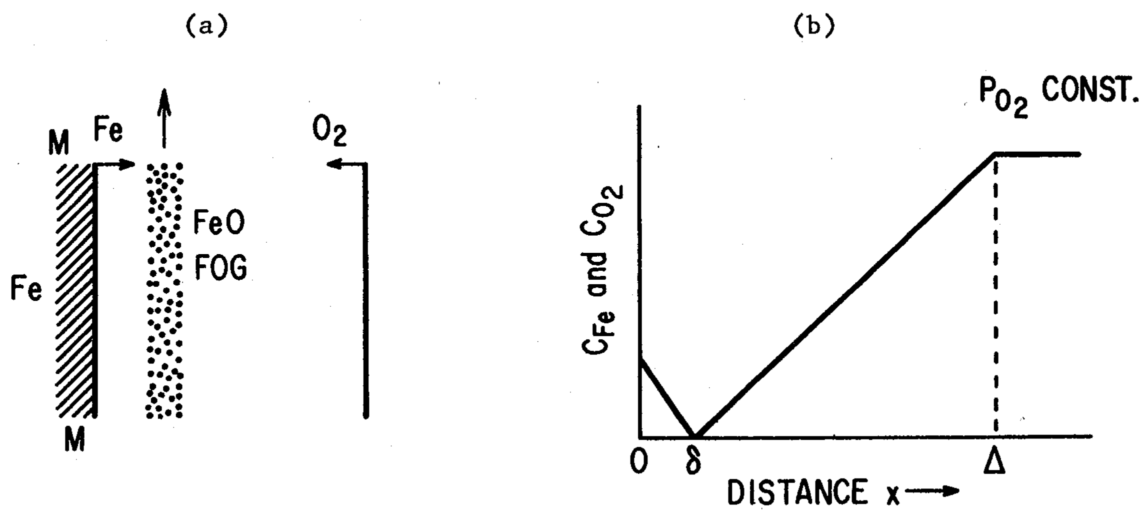


Fig. 1. Schematic representation of fume formation.

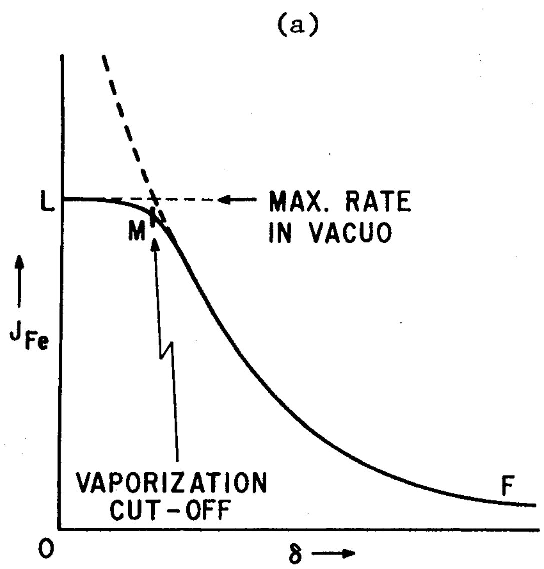
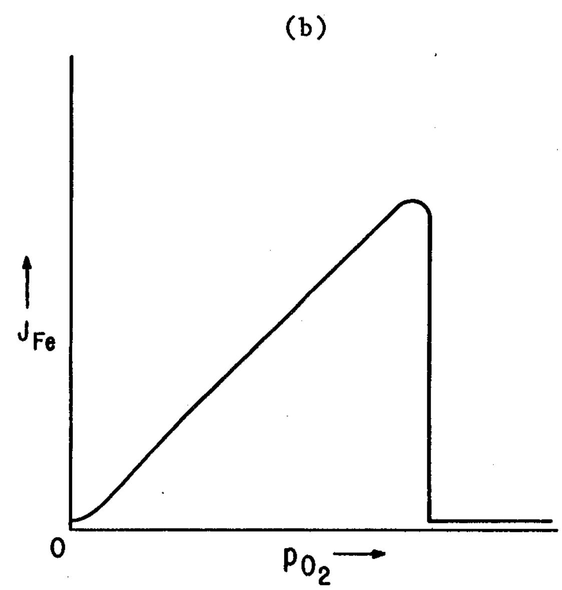


Fig. 2.



Schematic diagram showing the increase of fume formation with increasing oxygen concentration in the gas.

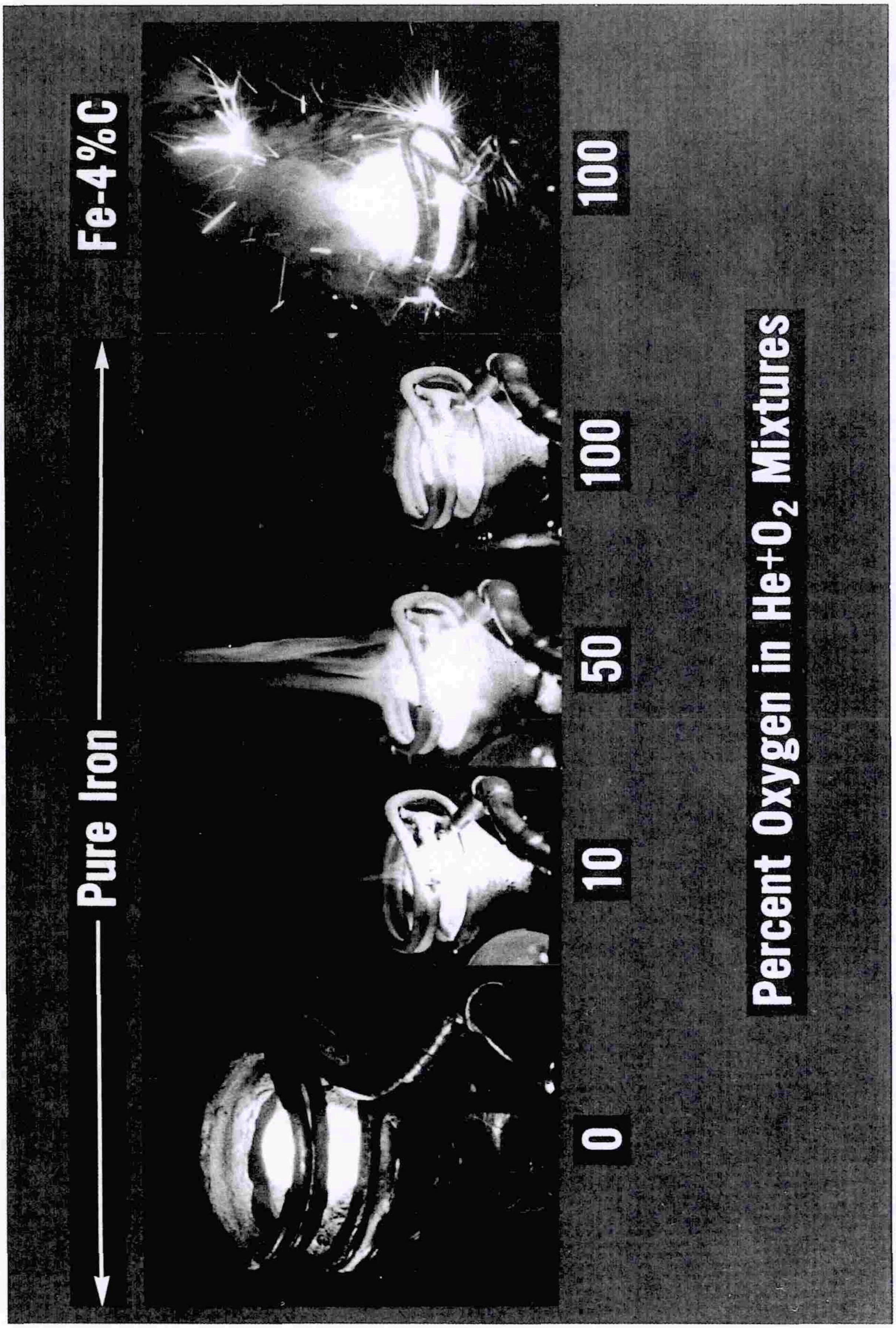


Fig. 3. Vaporization of levitated iron melts in helium-oxygen atmospheres.

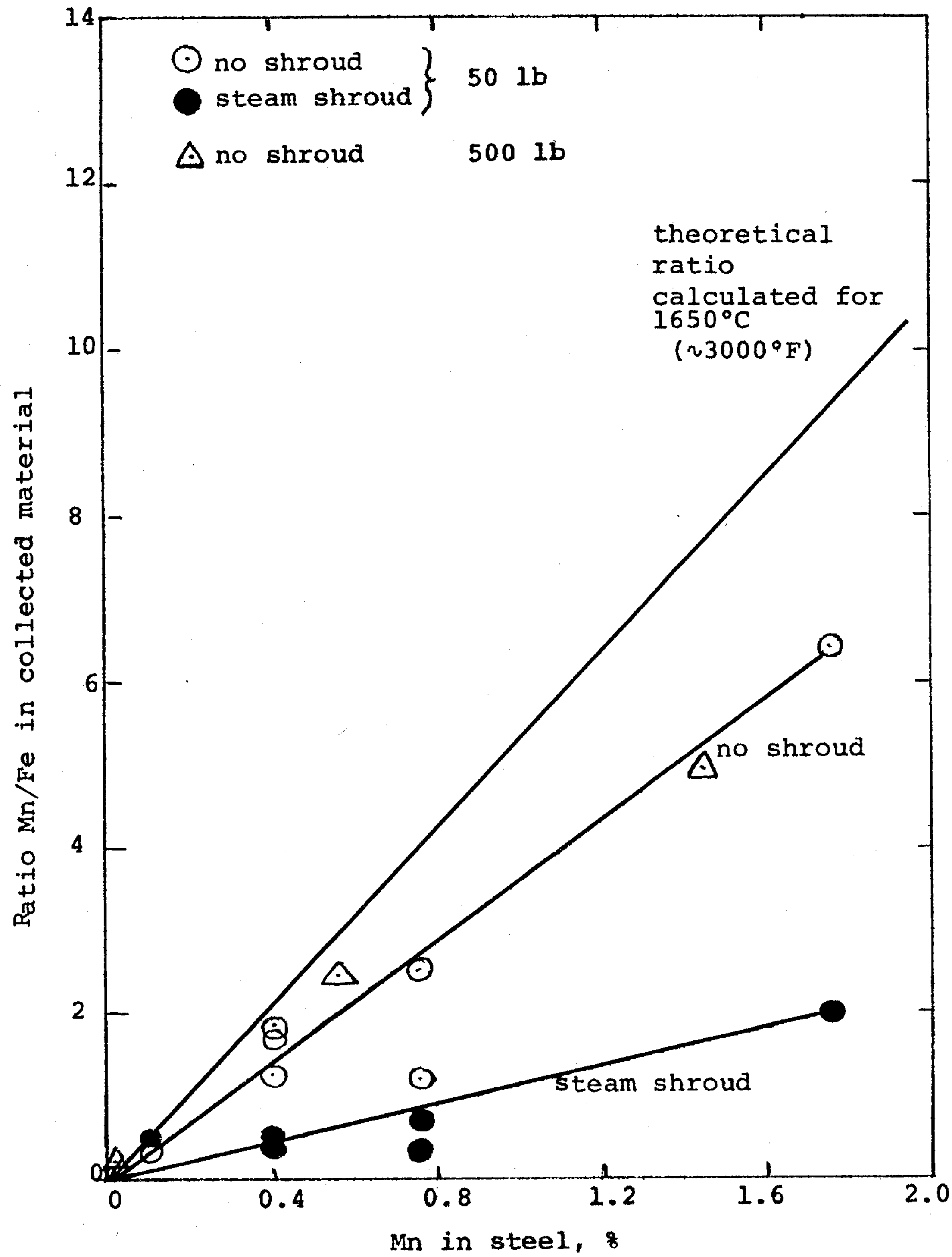


Fig. 4. Mn/Fe ratio in the material collected during the tapping of a 50-lb steel melt of indicated Mn contents, with and without steam shrouding; the results from the 500-lb tests are also indicated.

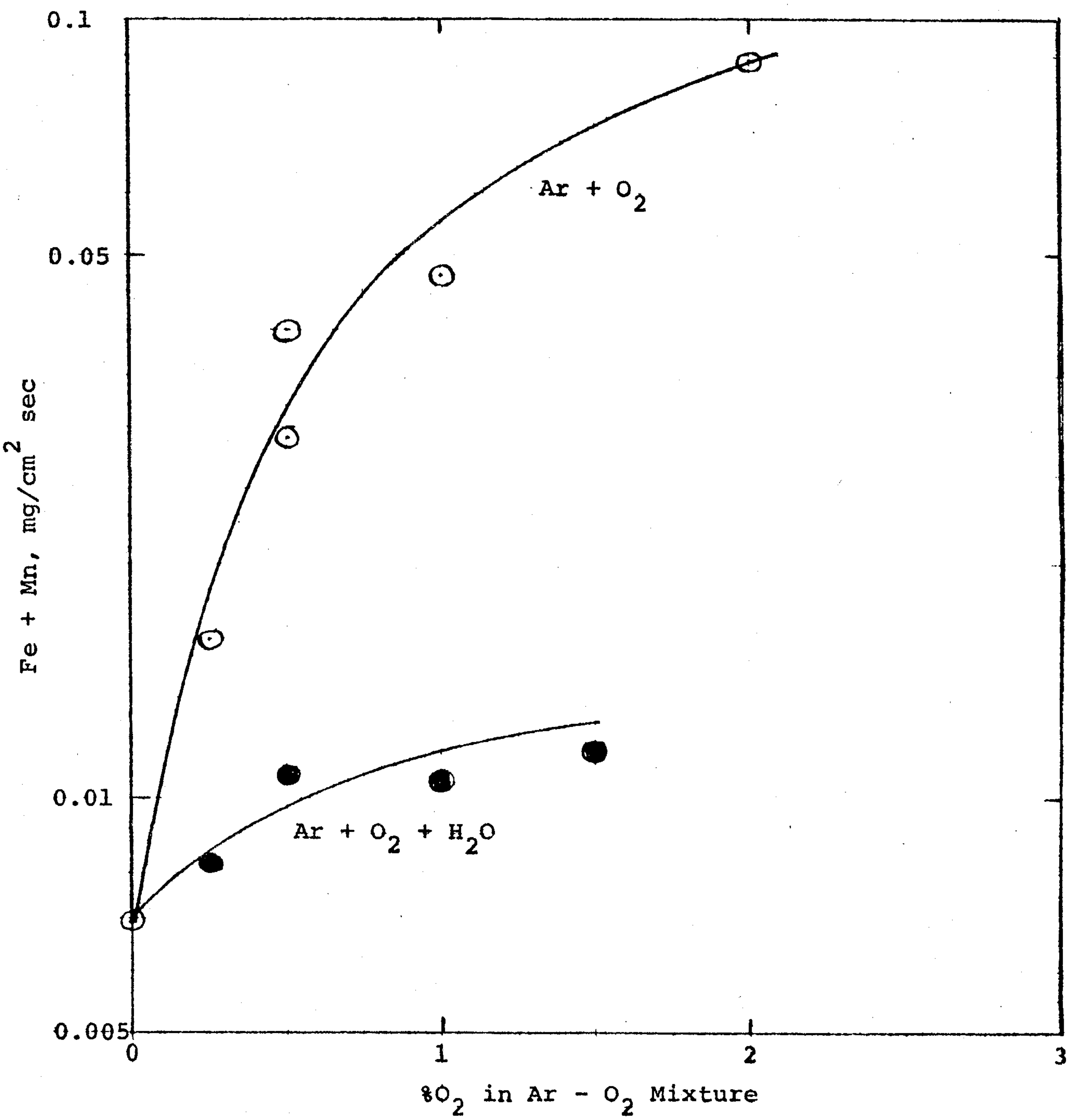


Fig. 5. Total amount of iron and manganese emitted from Fe + 1% Mn liquid melts during blowing with Ar + O_2 mixtures with and without water injection.

Chemical Characterization of Slag Emissions at Duquesne No. 6 Blast Furnace

J. F. Kelly -- Analytical Sciences

A. W. Simon -- Environmental Studies

1. SUMMARY

Huge reductions have been made in the fume emissions from molten-iron transfer in blast-furnace casthouses. However, the noncapture supression techniques, which employ a shrouding of the molten-metal surface with either steam or a natural-gas flame, are ineffective in controlling the visible, but low mass, emissions from molten slag. A program was undertaken at the Duquesne No. 6 blast furnace to characterize the slag fumes chemically and thus provide a basis for the development of slag-emission control techniques that would meet environmental regulations.

With the aid of a number of analytical techniques, it was found that the slag fumes are primarily a complex mixture of sulfur oxide--potassium compounds. Specific compounds that have been identified, to date, include potassium bisulfate, potassium sodium sulfate, and possibly potassium thiosulfate.

The chemical characterization information should be useful in developing strategies for the control of slag emissions at all blast furnaces.

2. DISCUSSION

Flame- and steam-suppression devices have been installed at the Duquesne No. 6 blast furnace (Mon Valley Works) to control fugitive emissions from a casthouse by a noncapture technique. Observations made by the United States Environmental Protection Agency (USEPA) on November 3, 4, and 5, 1982, revealed that, while such techniques are highly effective in reducing emissions from the molten iron, compliance with applicable visual-emission regulations had not been achieved, apparently because of emissions from the slag runners. Until the development and successful application of flame- and steam-suppression devices to prevent the formation of the reddish-brown iron oxide fumes, it was not realized that the light-colored slag emissions would have a measurable impact on casthouse fugitive emissions as measured by the visual-emissions opacity test. The working mechanism of molten-iron fume suppression is to reduce the oxygen available to the iron surface, thus reducing the generation of iron oxide fume (1)*. However, it appears that the fume released from the slag runners may be generated by some mechanism other than oxidation. As a preliminary step to elucidating this mechanism, which may serve as a basis for developing corrective actions, it was necessary to chemically characterize the slag emissions. A literature survey indicated that no information has been published on the nature of the fumes obtained from molten blast-furnace slag.

A sampling program was initiated to provide slag-fume samples for various analytical techniques. Samples of fume were collected on a membrane filter about four feet above the east taphole slag runner of the blast furnace during casting. The sampling point is shown in Figure 1, a schematic diagram of the casthouse runner arrangement. Flame suppression was used to eliminate metal-oxide fumes from the trough area, iron runner, and hot-metal cars.

A modified USEPA Method 8 procedure was used to determine the sulfur trioxide and sulfur dioxide content above the runner. The results are shown in Table I.

2.1 SCANNING-ELECTRON MICROSCOPY (SEM)

Samples were collected over the slag runner and east taphole on Nuclepore polycarbonate 0.8 micrometre (um) pore-size filters for analysis by SEM. These samples were collected over periods of 5 to 30 minutes. The casts during which these samples were collected are identified in Table II.

A section of each filter was analyzed by SEM energy-dispersive X-ray spectroscopy (EDS). An EDS X-ray spectrum was obtained from a 4-millimetre (mm)-square area on each filter. This technique measures the relative atomic abundance of all elements heavier than neon (atomic No. 10). Elements such as carbon, nitrogen, and oxygen

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* See References.

cannot be detected. The striking feature of these spectra (Figure 2) is that the predominant elements found on these filters are potassium and sulfur. The relative elemental peak heights or areas are a measure of atomic abundance. This analytical method exhibits a reduced sensitivity to particles larger than about 1 micrometre which should provide a good measure of the composition of particles responsible for visual opacity because the small particles have a greater effect on opacity.

The high-magnification micrographs show the potassium-sulfur material to be in the form of small (ca. 0.1- to 0.5-um diameter) particles with smooth surfaces. The iron-containing particles are typically larger (ca. 1 to 5 um) and spherical. EDS X-ray spectra of individual particles show the iron to be concentrated in particles that are essentially pure iron oxide containing very little potassium or sulfur, while the potassium-sulfur particles have no iron associated with them. The atomic potassium-to-sulfur ratio (K/S) for each sample is given in Table II. For reference, potassium sulfate has a ratio of 2.0, while the bisulfate ratio is 1.0. There are numerous other possible compounds and other analytical techniques have been used to identify the specific chemical species present on these filters.

2.2 CHEMICAL ANALYSIS

Typically, only about 1 to 5 milligrams (mg) of fume sample could be collected on a membrane filter during an entire cast. This required the development of micro methods to obtain a chemical characterization of the fumes. After several attempts, a procedure based on a combination of atomic absorption spectroscopy and ion chromatography was developed. For the wet chemical analysis, Millipore Fluoropore (Teflon) membrane filters (0.2-um pore size, 47-mm diameter) were found to be satisfactory and did not produce the high chemical blank values that had been obtained when Alundum thimbles were used to collect the fumes. Some tests were made with 0.8-um pore-size polycarbonate filters, but the Fluoropore filters were preferred for the chemical workup.

When a fume sample on a Fluoropore filter was received, it was weighed and then cut in half. One portion was extracted with dilute hydrochloric acid and analyzed for the metallic cations by atomic absorption spectroscopy. The second half was extracted with water and analyzed for anions such as sulfate, fluoride, and chloride by ion chromatography. The extracted halves of the membranes were dried and weighed to obtain the weight of the residual sample.

Analyses of two different slag-runner fume samples are presented in Table III. The major components are iron, potassium, and sulfate. The K/S ratios were 0.95 and 1.23 in the A sample and B sample, respectively.

Three spoon samples of molten runner slag were taken at the blast furnace on three separate days to obtain a more complete analysis (Table IV) than is normally obtained on production samples.

The data indicate that over 90 percent of the sulfur is present as sulfide. There are small measurable amounts of sulfate present, but this sulfate may have formed by air oxidation of sulfur species after the slag left the furnace taphole.

2.3 SCANNING AUGER ANALYSIS

To obtain additional information on the chemical composition of the slag fumes, the material collected on the membranes was analyzed by an X-ray fluorescence technique with the use of a scanning Auger multiprobe analyzer. With a thin-window detector, the unit is capable of analyzing elements above atomic No. 6 (carbon). In particular, because this technique can measure oxygen directly, it would assist in determining whether the oxygen is present in the fume sample as collected, or as a result of hydrolysis or oxidation in the workup for the chemical analysis of these samples.

The scanning Augėr X-ray analysis (Table V) indicates that potassium, sulfur, and oxygen are the major components present in the fume solids collected on the membrane sampling filter. The K/S ratios for three fume samples from different casts were 1.26, 0.94, and 1.11. These agree with the SEM results, indicating an average K/S ratio of about 1. An attempt was made to calculate the atomic oxygen-to-sulfur (O/S) ratio, but a correction had to be made for the oxygen present as the metal oxides. Independent X-ray diffraction structural analyses and optical microscopy indicated that the iron is present mainly in the magnetite form. For the purpose of the correction calculation, it was assumed that silicon and aluminum are present as silica and alumina. The corrected O/S ratios for the three samples were 3.29, 3.78, and 4.79. These results tend to confirm the chemical analysis results (Table III) that the oxygen associated with the sulfur is present predominantly as sulfate ion (O/S ratio = 4.0) in the fume solids collected on the membrane. The potassium-to-sodium (K/Na) ratios were 5.7, 5.8, and 7.8. The wet chemical analysis (Table III) had indicated a 4:1 K/Na ratio on samples collected at other times.

2.4 FOURIER-TRANSFORM INFRARED SPECTROSCOPY

Samples of the fume solids were examined by Fourier-transform infrared spectroscopy. This technique has the capability of repetitively scanning a surface and accumulating low-intensity infrared spectra in a computer memory. Fume samples collected on polycarbonate and Teflon membranes were examined in this manner, but it was found that background absorption from the membrane materials interfered with the sample spectrum. It was then determined that a small quantity of the solids could be combined in a potassium bromide pellet and the infrared spectrum could be accumulated from the pellets. The resultant spectrum indicated that the fume solids contained sulfate and bisulfate species.

2.5 X-RAY DIFFRACTION ANALYSIS

Samples of the slag fumes were examined by X-ray diffraction analysis. To provide an X-ray diffraction pattern, the sample components must be crystalline and the particles should have an adequate crystallite size. Iron was found to be present in all the samples as magnetite. Three potassium-sulfur compounds were identified: potassium bisulfate, potassium sodium sulfate, and tentatively potassium thiosulfate. The three compounds were not present in all of five samples examined. All samples contained additional components that have not been identified. It is of interest that all three of the potassium-sulfur compounds identified have a 1:1 K/S ratio. Attempts to identify potassium sulfate (K_2SO_4, K/S ratio = 2) were made, but no X-ray evidence for its presence was obtained.

2.6 POTASSIUM REACTIONS WITHIN THE BLAST FURNACE

Estimates of potassium losses, based on particulate fugitive emissions [5], are not of sufficient magnitude to affect the potassium analysis of the slag. This suggests that the chemical interactions involving potassium loss must also be operating within the furnace on a much greater scale. Potassium compounds can leave the furnace stack as volatile or entrained species in the top gas, or can be deposited on the furnace walls as a relatively intractable solid. The potassium enters the furnace from the coke or ore, mainly as some complex form of potassium silicate. Thermodynamic considerations [2,3,4] indicate that of all the potassium compunds that may exist in the high temperature region of the furnace, potassium silicate is among the most difficult to reduce to potassium metal (boiling point of 766° C). Such high-reduction temperatures 1300 to 1550° C) are only encountered in the bosh and hearth areas where the following reations may take place:

$$K_2SiO_3 + C \longrightarrow 2K + SiO_2 + CO$$

$$K_2SiO_3 + CO \longrightarrow 2K + SiO_2 + CO_2$$

However, in the presence of lime, an exchange reaction may take place:

$$K_2SiO_3 + CaO \longrightarrow K_2O + CaSiO_3$$

In the reducing atmosphere of the furnace, the potassium oxide is rapidly reduced to potassium metal:

$$K_2O + C \longrightarrow 2K + CO$$

It is well established that the buildup and recycle of potassium inside a furnace can be regulated, to some extent, by lowering the basicity of the slag through control of the amount of available lime.

Fukutake and coworkers [6] developed an empirical relationship for the vaporization rate of potassium from slag within the blast furnace, based on slag basicity, temperature, and surface area per unit mass of slag. Of the various factors evaluated in that study, it was determined that slag temperature had the greatest effect on potassium vaporization rates. Efforts are in progress to identify factors involved in the relationship between potassium and slag-emission rates in the casthouse.

2.7 CONCLUSIONS

The flame and steam fume-suppression techniques that were developed for iron runners do not appear to have any effect on the fumes evolved from the slag runners. To assist in the development of slag-fume-suppression strategies, it is necessary to characterize the chemistry of the fume and elucidate the mechanism by which it is formed. A number of analytical techniques were used to characterize slag-fume samples obtained during casting at the Duquesne No. 6 blast furnace.

Scanning-electron microscopy and X-ray fluorescence analyses indicate that potassium and sulfur are the major components, that the K/S ratio is close to 1.0, and that iron is present in all samples as discrete particles not associated with either potassium or sulfur. The iron is found as iron oxide in all of the slag-fume samples, but is believed to be due to cross contamination in the casthouse atmosphere from stray fumes that escape the flame-suppression devices at the trough, iron runners, and hot-metal cars. Chemical microanalyses confirmed the K/S ratio of 1 and suggested that the sulfur was present mainly as sulfate ion. X-ray analysis for oxygen confirms that the sulfate is present in the fume sample, as collected on the membrane, and is not an artifact of the chemical workup. Fourier-transform infrared spectroscopy showed the presence of sulfate and bisulfate ions. X-ray diffraction analyses confirmed the presence of magnetite, potassium bisulfate, potassium sodium sulfate, and possibly potassium thiosulfate. Except for the magnetite, none of the identified species was present in all of the samples. The samples all contained additional compounds that have not been identified. It is significant that the identified potassium compounds have a K/S ratio of 1. Because of its stability as a vapor at high temperature [7], potassium sulfate (K/S = 2) was specifically looked for in the fume samples, but no evidence for its presence was found.

The chemical characterization evidence suggests that the slag fume may be formed by a reaction between potassium species and sulfur oxides to form a transient intermediate that has not yet been identified. Whether the reaction takes place in the slag after it leaves the taphole or whether it takes place above the slag surface is not clear. Visual observation indicates that the slag emissions form an attached plume which suggests that the fume is already formed as it leaves the slag surface.

One purely speculative possibility is that the transient fume intermediate is potassium pyrosulfate, which can be formed by a number of possible pathways from potassium, potassium oxide, or potassium sulfate by reactions involving either sulfur trioxide or sulfur dioxide and oxygen. It is well known that potassium pyrosulfate is easily hydrolyzed in the presence of water to form potassium bisulfate, which has been identified in the fume sample:

$$K_2S_2O_7 + H_2O \text{ ---> } 2\ KHSO_4$$

It is very likely that the potassium bisulfate is formed on the membrane-collection surface because it does not have the thermal stability to persist in the molten-slag environment and, in addition, there is probably no readily available hydrogen source at the slag surface. The potassium bisulfate could undergo additional reactions on the membrane surface because of further contact with reactive species, such as sulfur dioxide, sulfur trioxide, oxygen, and moisture that are present in the air above the slag runner. A complex mixture of potassium sulfur compounds has been observed on the collection-membrane surface.

3. ACKNOWLEDGEMENTS

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Table I

Analysis of Slag-runner Fume for Sulfur Oxides
(Modified USEPA Method 8)

Test No.	Sulfur Trioxide, (SO_3), grams*	Sulfur Dioxide, (SO_2) grams*
1	0.042	0.065
2	0.052	0.246

* Collected in a 20-cubic-foot sample.

U. S. STEEL CORPORATION, RESEARCH, MONROEVILLE, PA.

Table II

Scanning-Electron Microscopy (SEM)
Analysis of Slag Fumes

SEM No.	Potassium/Sulfur Ratio
2245	1.0
2247	1.0
2248	1.0
2249	1.0
2252	0.7
2253	1.2
2254	1.1
2255	0.8
2267	0.8
2268	1.5
2269	0.9
2270	0.8
2271	0.9
2272	0.8
2279	1.8
2280	1.0
2281	0.9
2282	0.9
2276	0.9
2277	1.1
2283	1.0
2284	1.0
2285	1.3
2287	1.2
Average	1.0

U. S. STEEL CORPORATION, RESEARCH, MONROEVILLE, PA.

Table III

Chemical Analysis of Duquesne Slag-Runner Fumes

	A		B	
	Wt %	Atomic Ratio*	Wt %	Atomic Ratio*
Lithium	0.03		0.15	
Sodium	3.11	0.25	2.56	0.24
Potassium	21.0	1.00	17.8	1.00
Calcium	0.42		0.51	
Magnesium	0.16		0.12	
Iron	6.85		6.93	
Manganese	0.21		0.22	
Sulfate	54.3	1.05 (as S)	35.5	0.81 (as S)
Fluoride	0.0		0.06	
Chloride	0.18		0.05	
Total	86.3		63.9	

* Calculated with K = 1.00

U. S. STEEL CORPORATION, RESEARCH, MONROEVILLE, PA.

Table IV

Duquesne No. 6 Blast-Furnace
Runner-Slag Analysis

Component	Weight Percent		
	Sample A	Sample B	Sample C
Manganese	0.33	0.27	0.25
Silicon	17.3	17.83	17.78
Aluminum	4.48	4.31	4.59
Calcium	30.66	30.15	30.31
Magnesium	4.11	4.26	4.08
Iron	0.62	0.50	0.25
Zinc	0.004	0.003	0.004
Titanium	0.19	0.17	0.20
Fluoride	0.20	0.19	0.16
Chloride	0.01	0.02	0.02
Lithium	0.009	0.009	0.011
Sodium	0.23	0.16	0.13
Potassium	0.41	0.34	0.21
Total Sulfur	1.63	1.52	1.62
Sulfide	1.47	1.40	1.46
Sulfate	<0.01	0.022	0.012

U. S. STEEL CORPORATION, RESEARCH, MONROEVILLE, PA.

Table V

X-ray Analysis of Slag Emission Samples With Scanning Auger Multiprobe

Sample	Membrane Area No.	Atom Concentration, %							Atomic Ratios			
		Fe	K	S	Si	Al	Na	O	K/Na	K/S	O/S	Oc/S*
A	1	4.6	17.3	13.7	2.2	0.6	3.0	58.5	5.8	1.26	4.27	3.44
	2	6.8	17.8	14.3	2.5	0.6	3.6	54.4	4.9	1.24	3.80	2.65
	3	3.6	17.4	13.5	2.1	0.2	2.7	60.4	6.4	1.29	4.47	3.79
								Av.	5.7	1.26	4.18	3.29
B	1	5.8	15.0	15.3	2.6	1.3	1.8	58.1	8.3	0.98	3.80	2.82
	2	2.3	13.7	14.2	0.6	0.2	1.7	67.4	8.1	0.96	4.75	4.42
	3	2.8	12.8	14.4	1.4	0.5	1.8	66.3	7.1	0.89	4.60	4.10
								Av.	7.8	0.94	4.38	3.78
C	1	4.2	11.0	10.0	4.8	0.3	2.2	67.5	5.0	1.10	6.75	5.19
	2	3.9	12.3	11.0	4.3	0.3	2.0	66.2	6.2	1.12	6.02	4.72
	3	5.2	12.3	11.1	4.0	0.4	2.0	65.0	6.2	1.11	5.86	4.46
								Av.	5.8	1.11	6.21	4.79

* Oxygen values associated with sulfur are corrected (Oc) by assuming that the following metal oxides are present: Fe_3O_4, SiO_2, and Al_2O_3.

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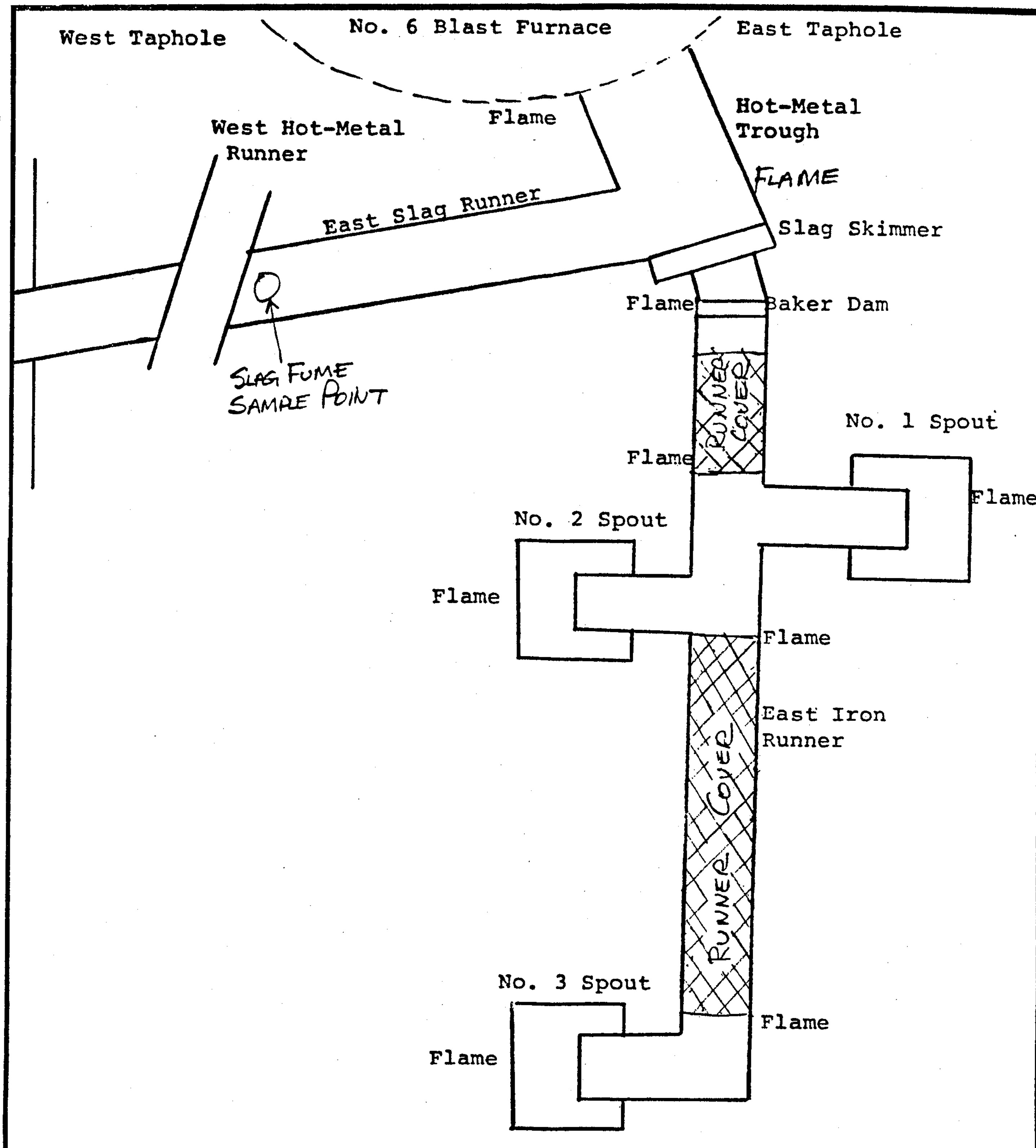
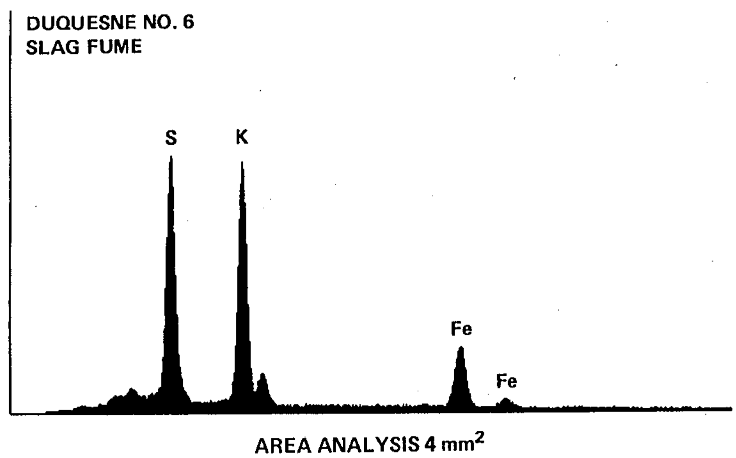


Duquesne No. 6 Blast-Furnace Runner System

Figure 1



X-ray Spectrum of a Slag Fume Sample

Figure 2

Duquesne No. 6 Blast-Furnace Runner-Emission Measurements

D. L. Trozzo -- Environmental Studies

1. SUMMARY

Large reductions in the emission of fumes from blast furnace casthouses are being made as a result of the on going developments in local fume suppression techniques. Accordingly, it is important to quantitize the uncontrolled emissions for use such as in planning control strategies or in negotiating bubble trade-offs for the casthouse.

Mass-emission factors for iron and slag runners have been determined for the Duquense No. 6 blast-furnace by Corporate Research, in cooperation with Duquesne Engineering and Operating personnel. A specially designed fume-collection system was employed to capture and measure runner emissions from a known runner segment. Emissions of 1.02 and 0.33 pounds per hour per square foot of runner surface were determined for iron and slag runners, respectively. By applying these factors over the entire runner system, average total runner emissions of 0.15 pound per ton of hot metal were estimated. We are 95 percent confident that the true value is within ± 0.05 pound per ton of the estimated value. Because of expected differences in iron temperature and chemistry, as well as in runner material and configuration, these factors may not apply to other casthouses.

2. DISCUSSION

2.1 INTRODUCTION

The development of a fume suppression system at the No. 6 blast furnace casthouse has resulted in large reductions in the emissions from this source. To evaluate the accomplishments of this system, a knowledge of the quantity of uncontrolled emissions is required.

Reported estimates of emissions from uncontrolled blast-furnace casthouses range from 0.2 to 0.6 pound per ton of hot metal (lb./ton), as measured by Environmental Protection Agency (EPA) Method 5.[1)*] These emission factors are typically determined for the aggregate exhaust fume, including taphole, trough, runner, and spout emissions as measured at the baghouse inlet for the casthouse having a full-house evacuation-control system. Thus, determination of emission factors on an individual source basis is nearly impossible. Because much attention is presently focused on the local capture and suppression of individual fume sources within the casthouse, determination of specific source emission factors would be useful in determining overall casthouse emission-control strategies.

Accordingly, a test procedure has been developed for the determination of iron- and slag-runner emissions which utilizes a specially designed fume-collection system. Emission factors in terms of pound of particulate per hour per square foot of runner surface may be determined by this method. With knowledge of runner lengths and flow duration, emission factors in terms of pound per ton of hot metal (lb./ton) may also be calculated. An initial test series demonstrating this technique was successfully performed at the Duquesne No. 6 blast furnace and emission factors have been calculated. The newly developed procedure is suitable for the determination of runner emission factors for casthouses of any runner configuration.

2.2 EXPERIMENTAL METHOD

To quantify runner emissions for the Duquesne No. 6 blast furnace, emissions from a known runner segment were captured with a portable hood and fan and measured in a 14-inch-diameter circular duct using EPA Method 5. A diagram of the runner-emission measurement system is presented in Figure 1. A flow-control damper was installed on the exhaust side of the 4000-actual-cubic-foot-per-minute fan to facilitate adjustment of the null capture flow. Null flow exists when the hood face velocity is maintained near the fume rise velocity, thus permitting collection of a representative sample over the defined runner segment.

An initial velocity traverse was performed from two 90-degree opposed sampling ports located eight-duct diameters downstream from the hood to determine flow conditions. In view of the flat undisturbed velocity profile present, it was elected to perform emission measurements isokinetically at a single average velocity point.

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* See Reference.

The collection hood was designed with a 13-inch by 36-inch rectangular opening and support pads to allow placement directly over the iron or slag runner. Mineral wool insulation was applied to all interior hood surfaces prior to testing and successfully prevented thermal warping during the test.

The No. 6 blast furnace has two independent tapholes and runner systems. Due to safety considerations, testing could only be performed on the east system which has 184 feet of iron and slag runners. A diagram of the east runner system is presented in Figure 2. Due to their similarity, testing performed on the east side is considered to be representative of the west runner system also. The average runner cross section was approximately one foot wide at the slag or hot-metal surface and 2-1/2 feet wide at the level of the casthouse floor. Slag or hot-metal surfaces were typically one foot below the casthouse floor. For hot-metal surfaces were typically one foot below the casthouse floor. For hot-metal testing, the collection hood was located over a segment of the main runner between the Baker Dam and the No. 1 spout. This allowed collection of the longest duration fume sample since all hot metal passed the runner test segment enroute to the spout. Slag-runner tests were performed at a location approximately 20 feet downstream from the iron trough. Visual inspection of runner fume during the survey indicated that fume quantities generated at both test segments were representative of their respective runner. Any variation in emission rate between the sample segment and the iron-runner section between the second and third spouts would have little influence on the calculation of total casthouse emissions because of the short iron-flow duration to the third spout.

A volume flow rate in excess of 2000 standard cubic feet per minute (scfm) was required on initial test runs to adequately capture runner emissions. These runs were not considered acceptable, however, since a gap of one foot or more between the hood and hot metal permitted entrance of extraneous fume into the hood. During strong-wind conditions, the channeling of fume along the runner and into the hood was particularly acute. To help alleviate this interference, two 1/8-inch steel-plate skirts were fabricated and suspended from the sides of the hood to a distance of within several inches from the hot metal. Through careful damper adjustment and sealing of the hood skirts, null capture flows in the range of 800 scfm were attained for later test runs. The above flow translates into an average hood face velocity of about 200 feet per minute (ft./min.), which is roughly equal to the estimated fume-rise velocity above the runner. A fume-capture segment, measuring approximately 20 inches by 12 inches, was defined by the distance between the two skirts and the width of the runner stream. Length and width measurements were recorded for each test. However, runner widths were sometimes highly variable during a particular cast and should only be considered as approximations.

A series of 10 hot-metal-runner and 10 slag-runner measurements was performed during the period from June 17 through July 28, 1982. Testing commenced with the flow of molten slag or iron under the hood and concluded shortly after the plugging of the taphole. The average test length was about 40 minutes. All fieldwork and laboratory analyses were performed in accordance with EPA Method 5 with the exception of the aforementioned average sampling point within the duct.

In addition to the determination of mass emissions, samples of iron- and slag-runner fume were also obtained from the test duct for characterization by scanning electron microscopy -- automatic image analysis.

During each test run, flow duration per runner section was recorded as well as the runner material in use during the cast. Hot-metal chemistry and temperature information were secured from the cast sheets, and an estimate of total tons of iron per cast was made by Duquesne operating personnel.

2.3 RESULTS

Dust loading in units of pounds per hour (lb./hr.) was calculated for each test run as the product of dust concentration and duct flow volume. Average runner-emission factors of 1.02 and 0.33 pound per hour per square foot of runner surface (lb./hr./ft.^{2}) were calculated for the iron and slag runners, respectively, by dividing dust loading values by the appropriate runner surface area. These results are presented in Tables I and II. Values for iron-runner tests 1 through 4 and slag-runner test 1 were not included in the averages due to excessive fume infiltration from outside the designated runner-sampling segment.

For purposes of calculating runner emissions in lb./ton, individual dust-loading values were first divided by the length of the runner segment sampled to yield an emission factor in pounds per hour per foot (lb./hr./ft.). This procedure assumes uniform runner width at any given time and, therefore, dispenses with the need for measuring runner widths over the entire runner system during the cast. Average values of 0.74 and 0.28 lb./hr./ft. were determined for iron and slag runners, respectively, by this method. By applying these factors in conjunction with runner length and flow duration on both an average and an individual test basis, an average total runner-emission factor of 0.15 lb./ton was estimated. By applying the appropriate statistical techniques, we are 95 percent confident that the true value lies within $\pm$0.05 lb./ton of the estimated value. The contribution from iron alone was 0.11 lb./ton or nearly three times that of slag, which contributed 0.04 lb./ton. These results are summarized in Table III. Runner-emission-factor sample calculations, based on average and individual test values, are included in Appendix A.

Scanning electron microscopy -- automatic image analysis (SEM-AIA) was performed on two iron and two slag fume samples. This technique normally furnishes information on size distribution by weight based on individual particle size and density; however, by assuming spherical, unit-density particles, a weight distribution based on aerodynamic equivalent diameters has been constructed.

These data are summarized in Figures 3 and 4, respectively, as a plot of aerodynamic diameter versus cumulative percent by weight less than stated size. From these curves, it can be seen that in both cases 98 percent of the fume weight was derived from particles with aerodynamic diameters of under 130 microns ( ). A 130- unit density, spherical particle will attain a terminal settling velocity of about 100 feet per minute at standard conditions in still air. Because this velocity is well below the estimated fume-rise velocity and hood face velocity of 200 feet per minute, it is concluded that nearly all sampled fume would remain airborne and exit the casthouse.

An analysis of the detailed SEM-AIA results will be left to a future memorandum. Such an analysis may well further the understanding of fume generation from slag runners and its control.

Iron temperature, slag and iron chemistry, and runner material types are tabulated in Tables IV and V on a test-by-test basis. Any effect that changes in these parameters may have had on emission rates is not readily identifiable. Due to the large number of variables and the relatively small number of tests performed, correlation coefficients were not calculated.

2.4 CONCLUSIONS

This study has successfully demonstrated a technique for the measurement of slag- and iron-runner emission rates. A specially designed fume-collection system satisfactorily completed 20 sample runs at the Duquesne No. 6 blast furnace and sustained no hood damage as a result of the intense radiant heat from the runner. When operated with the aid of fume-deflection skirts, null capture flows in the vicinity of 800 scfm were required for adequate fume capture over the designated runner segment. In terms of emission-rate-per-unit area, the Duquesne iron runners show a three times greater emission factor than the slag runner. Total runner emissions of 0.15 lb./ton were determined for the No. 6 casthouse by applying these factors over the east runner system. It is concluded from particle-size-distribution data that nearly all sampled fume would remain airborne and exit the casthouse. The between-test variations exhibited by both data sets cannot be readily explained by differences in runner materials, iron temperature, or chemistry. Because even greater differences in temperature and chemistry, as well as runner material and configuration, would be expected among different casthouses, the emission factors generated at the Duquesne No. 6 blast furnace may not be representative of casthouses as a group.

3. REFERENCE

W. P. May, "Blast-Furnace Cast House Emission Control Technology Assessment," U. S. Environmental Protection Agency Report 600/2-77-231, 1977, p. 55.

Table I

Duquesne No. 6 Blast-Furnace Runner-Emission Measurement
Hot-Metal-Runner Test Results

Test No.	Length of Test, min.	Stack Temp., °F	H_2O vol %	Volume Sampled, scf (dry)	Flow, scfm (dry)	Dust, wt Acetone	Dust, wt Filter	Dust, wt Total	Dust Conc., gr/scfd	Dust Loading, lb/hr	Runner-Surface Sampled, inches	Runner-Emission Factor, $lb/hr/ft^2$	Runner-Emission Factor, lb/hr/ft	Isokinetic Sampling, %
1*	21.8	200	0.4	13.36	2146	0.0675	0.0479	0.1154	0.133	2.4	13 x 11 (No skirt)	2.4	2.2	93.3
2*	53.0	196	1.6	30.64	2061	0.0657	0.2190	0.2847	0.143	2.5	13 x 11 (No skirt)	2.5	2.3	91.7
3*	35.0	297	1.1	17.52	1637	0.0641	0.3190	0.3831	0.337	4.7	19.5 x 13	2.7	2.9	99.9
4*	65.0	257	0.9	34.85	1655	0.0331	0.3869	0.4200	0.186	2.6	19.5 x 12	1.6	1.6	105.2
5	58.0	333	0.9	34.09	812	0.0619	0.2358	0.2977	0.134	0.93	19.5 x 7	0.98	0.57	99.8
6	28.0	255	1.3	17.81	895	0.1343	0.2758	0.4101	0.354	2.7	22 x 10	1.8	1.5	98.2
7	37.0	260	1.2	22.92	858	0.0813	0.2015	0.2828	0.190	1.4	22 x 10	0.92	0.76	99.6
8	60.0	320	0.9	36.24	805	0.0699	0.2234	0.2933	0.124	0.86	21 x 9	0.65	0.49	103.6
9	58.0	210	2.2	29.84	737	0.0604	0.0980	0.1584	0.082	0.52	21 x 4	0.89	0.30	96.3
10	28.0	397	1.6	12.02	601	0.0760	0.1459	0.2219	0.284	1.46	21 x 11	0.91	0.83	98.6
Average									0.19			1.02	0.74	

* Not used in average
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Table II

Duquesne No. 6 Blast-Furnace Runner-Emission Measurement
Slag-Runner Test Results

Test No.	Length of Test, min.	Stack Temp., °F	H_2O, vol %	Volume Sampled, scf (dry)	Flow, scfm (dry)	Dust, wt Acetone	Dust, wt Filter	Dust, wt Total	Dust Conc., gr/scfd	Dust Loading, lb/hr	Runner-Surface Sampled, inches	Runner-Emission Factor, $lb/hr/ft^2$	Runner-Emission Factor, lb/hr/ft	Isokinetic Sampling, %
1*	25	196	1.5	12.79	1581	0.0183	0.0303	0.0486	0.058	0.78	21 x 8	0.67	0.44	100.3
2	29	267	1.1	17.05	788	0.0063	0.0625	0.0688	0.062	0.42	21 x 8	0.36	0.24	102.6
3	48	306	1.0	37.39	1069	0.0075	0.2022	0.2097	0.086	0.79	22 x 11	0.47	0.43	100.6
4	33	274	0.8	18.26	792	0.0254	0.0663	0.0917	0.077	0.52	21 x 11	0.32	0.30	96.5
5	45	242	2.0	27.95	843	0.0088	0.0800	0.0888	0.049	0.35	23.5 x 11	0.19	0.18	101.9
6	31	200	1.2	15.64	719	0.0588	0.0385	0.0973	0.096	0.59	20.5 x 8	0.52	0.34	96.7
7	51	356	0.8	26.40	684	0.0357	0.1294	0.1651	0.096	0.56	22 x 10	0.37	0.30	104.6
8	49	288	0.9	27.42	746	0.0254	0.0993	0.1247	0.070	0.45	22 x 10	0.29	0.24	103.9
9	35	270	2.1	20.05	766	0.0157	0.0600	0.0757	0.058	0.38	21 x 11	0.24	0.22	103.3
10	38	200	3.2	24.31	861	0.0133	0.0712	0.0845	0.054	0.40	21 x 11	0.25	0.23	102.6
Average									0.072			0.33	0.28	

* Not included in average

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Table III

Duquesne No. 6 Blast-Furnace
Runner-Emissions Factors
Individual Test Basis

Test No.	Type	Slag-Runner Emissions, lb/ton	Iron-Runner Emissions, lb/ton	Total Runner Emissions lb/ton
2	Slag	0.030	0.10	0.13
3	Slag	0.085	0.11	0.19
4	Slag	0.041	0.10	0.14
5	Slag	0.030	0.098	0.13
6	Slag	0.034	0.090	0.12
7	Slag	0.055	0.14	0.20
8	Slag	0.052	0.11	0.16
9	Slag	0.039	0.098	0.14
10	Slag	0.034	0.087	0.12
5	Iron	0.048	0.10	0.15
6	Iron	0.034	0.16	0.20
7	Iron	0.056	0.17	0.22
8	Iron	0.040	0.070	0.11
9	Iron	0.053	0.056	0.11
10	Iron	0.033	0.079	0.11
Average		0.04	0.11	0.15

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EPA-R5-2012-000596000366

Table IV

Duquesne No. 6 Blast Furnace
Operating Data - Hot-Metal-Runner Tests

Test No.	Runner Material	Iron Temp., °F	Hot-Metal Analysis, weight percent Si	S	P	Mn	Cr
1	Carborundum Ramfrax ST-3R	2645	0.85	0.047	0.050	0.61	0.05
2	"	2650	0.81	0.064	0.061	0.64	0.05
3	"	2760	1.20	0.012	0.057	0.73	0.06
4	"	2790	1.28	0.021	0.053	0.78	0.05
5	"	2760	1.04	0.019	0.067	0.81	0.09
6	Grefco Grefite 467-R	2680	0.79	0.050	0.058	0.74	-
7	"	2660	0.96	0.035	0.062	0.75	-
8	"	2640	0.82	0.091	0.048	0.58	0.06
9	"	2680	0.85	0.073	0.049	0.64	0.07
10	North American Narcarb	2720	1.16	0.043	0.043	0.70	0.06

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Test V

Duquesne No. 6 Blast Furnace

Operating Data - Slag-Runner Tests

Test No.	Runner Material	Slag Analysis, weight percent						
		SiO_2	Al_2O_3	CaO	MgO	K_2O	Fe	S
1	Grefco Grefite 467-R	37.67	7.93	46.24	9.13	0.27	0.13	1.86
2	"	38.10	7.77	44.27	9.42	0.25	0.14	2.02
3	"	38.16	7.62	44.93	9.28	0.29	0.31	1.59
4	"	38.43	7.67	43.42	9.11	0.05	0.14	1.55
5	"	38.05	7.48	43.20	9.99	0.50	0.13	1.50
6	"	36.74	8.15	45.08	10.90	0.10	0.21	1.67
7	"	37.10	8.74	44.50	10.42	0.19	0.05	1.72
8	"	36.76	8.49	44.18	10.61	0.17	0.05	1.64
9	"	38.88	8.38	43.28	9.60	0.37	0.21	1.63
10	"	39.13	8.36	43.23	9.34	0.43	0.22	1.57

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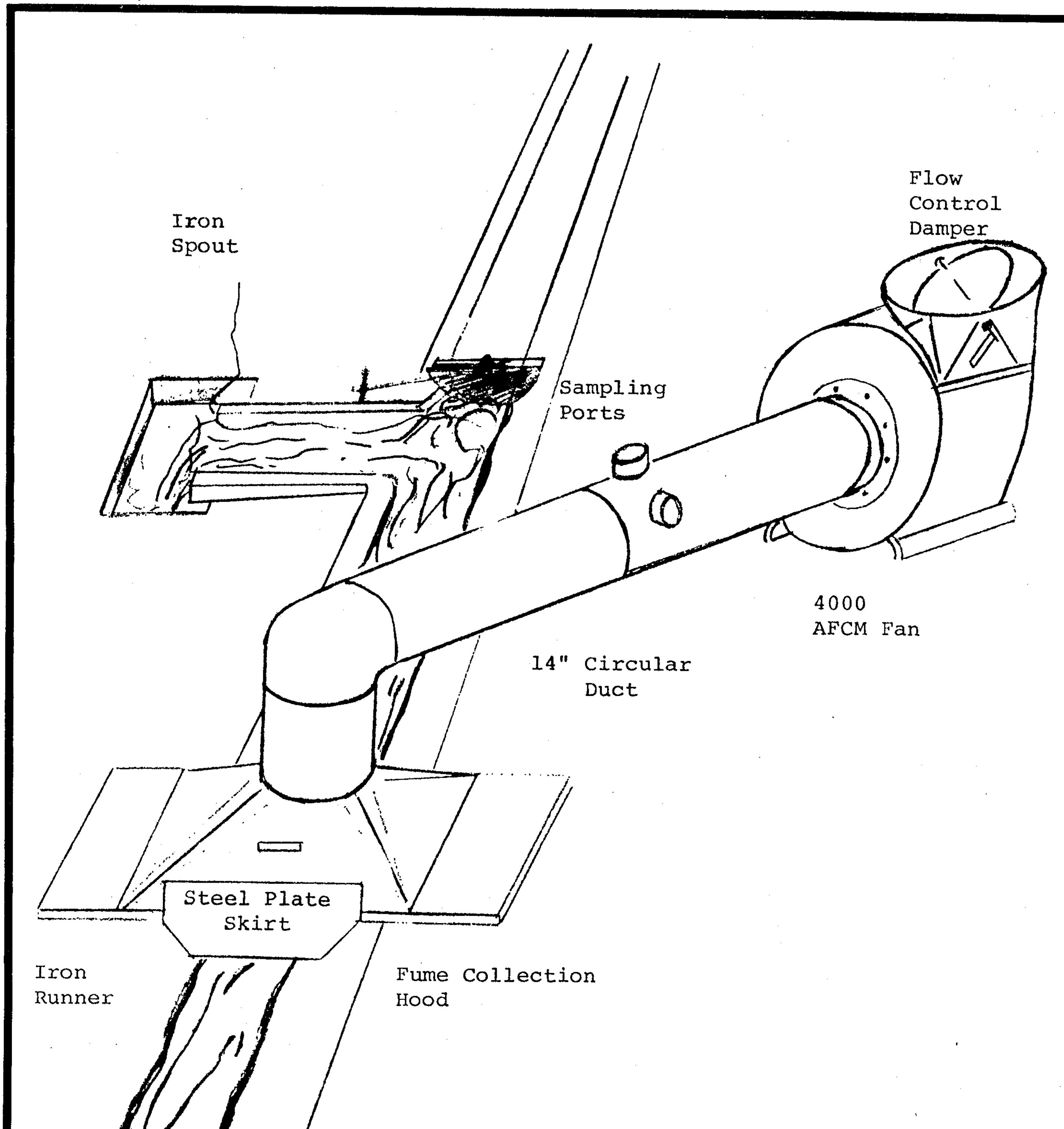
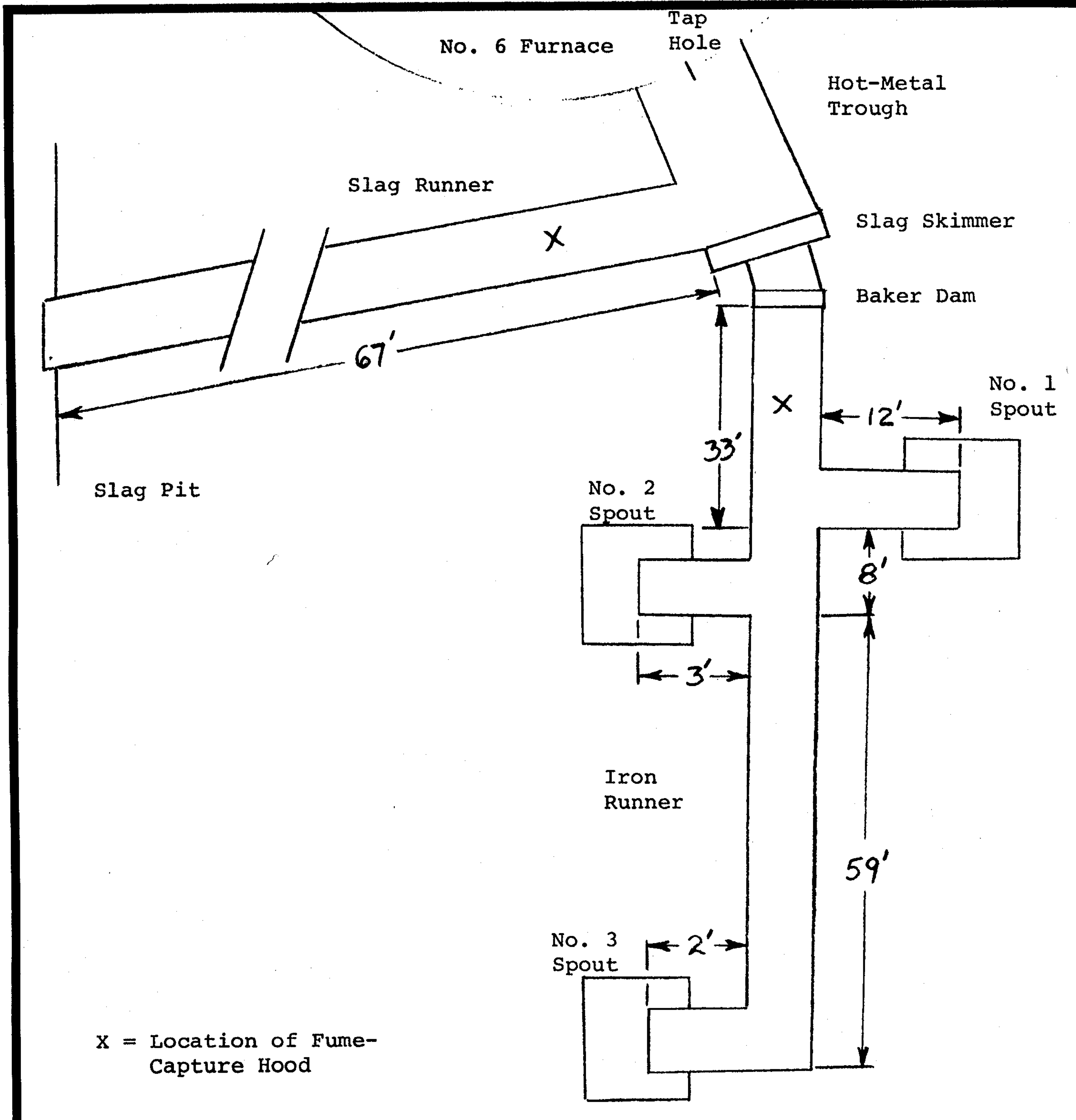


RUNNER EMISSION-MEASUREMENT SYSTEM

DRAWN BY	CHK'D BY	APPROVED BY	UNITED STATES STEEL CORPORATION	FIGURE NO.
DLT	CFH	DES	CORPORATE RESEARCH	1
DRAWING No.		PROJECT No. 18-F-584		
		DATE		

G-18242 REV. 1063



DUQUESNE NO. 6 BLAST-FURNACE EAST RUNNER SYSTEM

DRAWN BY	CHK'D BY	APPROVED BY	UNITED STATES STEEL CORPORATION	FIGURE NO.
DLT	CFH	DES	CORPORATE RESEARCH	2
DRAWING No.		PROJECT No. 18-F-584		
		DATE		

ATLAS LITHO CO., PGH., PA. 1025 CLEARPRINT

Duquesne No. 6 Blast Furnace, Iron-Runner Fume
Particle-Size Distribution

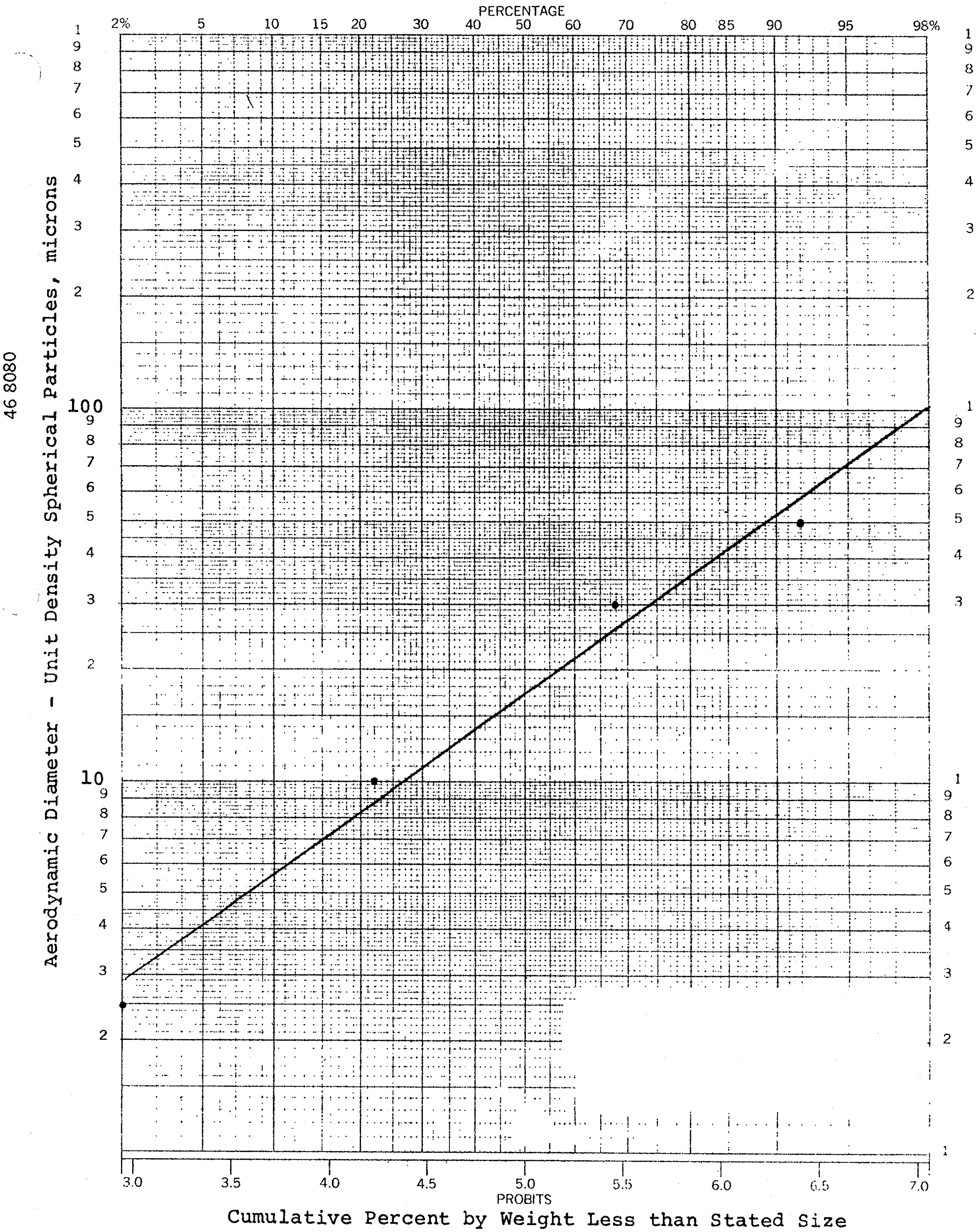
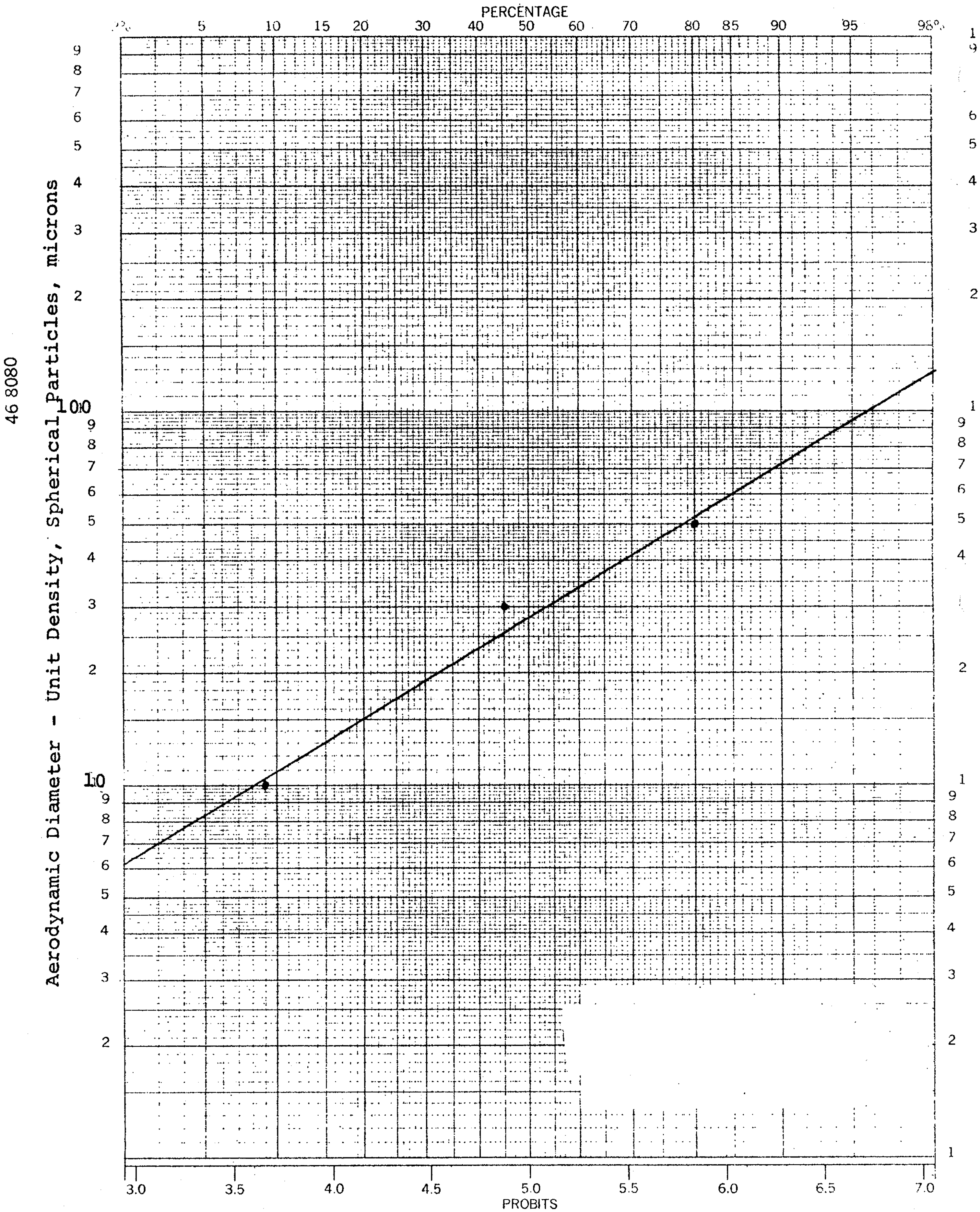


Figure 3

Duquesne No. 6 Blast Furnace, Slag-Runner Fume
Particle-Size Distribution



Cumulative Percent by Weight Less than Stated Size

Figure 4

APPENDIX A

Sample Calculation for Runner-Emission Factor Calculated on Individual Test Basis

Test No. 2, slag

$$\frac{\text{Emissions, lb}}{\text{Runner section}} = \text{(emission rate, lb/hr/ft)(length of runner section to spout, ft)(duration of iron or slag flow in runner section, min.)(1 hr/60 min.)}$$

Total Iron-Runner Emissions

Emissions to first spout

= 0.74 lb/hr/ft x 45 ft x 16 min. x 1 hr/60 min. = 8.9

Emissions to second spout

= 0.74 lb/hr/ft x 44 ft x 10 min. x 1 hr/60 min. = 5.4

Emissions to third spout

= 0.74 lb/hr/ft x 102 ft x 10 min. x 1 hr/60 min. = 12.6

Total = 26.9

$$\frac{\text{Iron-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{26.9}{260} = 0.10$$

Slag-Runner Emissions

= 0.24 lb/hr/ft x 67 ft x 30 min. x 1 hr/60 min. = 8.0

$$\frac{\text{Slag-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{8.0}{260} = 0.030$$

$$\frac{\text{Total runner emissions, lb}}{\text{Iron cast, ton}} = \frac{34.9}{260} = 0.13$$

APPENDIX A (Continued)

Sample Calculation for Runner-Emission Factor Calculated on Individual Test Basis

Test No. 6, iron

$$\frac{\text{Emissions, lb}}{\text{Runner section}} = \text{(emission rate, lb/hr/ft)(length of runner section to spout, ft)(duration of iron or slag flow in runner section, min.)(1 hr/60 min.)}$$

Total Iron-Runner Emissions

Emissions to first spout

= 1.5 lb/hr/ft x 45 ft x 9 min. x 1 hr/60 min. = 10.1

Emissions to second spout

= 1.5 lb/hr/ft x 44 ft x 17 min. x 1 hr/60 min. = 18.7

Emissions to third spout

= 1.5 lb/hr/ft x 102 ft x 4 min. x 1 hr/60 min. = 10.2

Total = 39.0

$$\frac{\text{Iron-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{39.0}{240} = 0.16$$

Slag-Runner Emissions

= 0.28 lb/hr x 67 ft x 26 min. x 1 hr/60 min. = 8.1

$$\frac{\text{Slag-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{8.1}{240} = 0.034$$

$$\frac{\text{Total runner emissions, lb}}{\text{Iron cast, ton}} = \frac{47.1}{240} = 0.20$$

APPENDIX A (Continued)

Runner-Emission Factor Calculated From Average Test Values

Average time to first spout	=	20.2 min.
Average time to second spout	=	19.7 min.
Remaining time to finish cast	=	5.3 min.
		45.2 min.
Average iron flow time	=	45.2 min.
Average slag flow time	=	37.3 min.

$$\frac{\text{Emissions, lb}}{\text{Runner section}} = \text{(average emission rate, lb/hr/ft)(length of runner section to spout, ft)(duration of iron or slag flow, min.)(1 hr/60 min.)}$$

Total Iron-Runner Emissions

Emissions to first spout

$= 0.74$ lb/hr/ft x 45 ft x 20.2 min. x 1 hr/60 min. $=$ 11.2

Emissions to second spout

$= 0.74$ lb/hr/ft x 44 ft x 19.7 min. x 1 hr/60 min. $=$ 10.7

Emissions to third spout

$= 0.74$ lb/hr/ft x 102 ft x 5.3 min. x 1 hr/60 min. 6.7

Total 28.6

$$\frac{\text{Iron-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{28.6}{270} = 0.11$$

Total Slag-Runner Emissions

$= 0.28$ lb/hr/ft x 67 ft x 37 min. x 1 hr/60 min. $=$ 11.6

$$\frac{\text{Slag-runner emissions, lb}}{\text{Iron cast, ton}} = \frac{11.6}{270} = 0.04$$

$$\frac{\text{Total runner emissions, lb}}{\text{Iron cast, ton}} = \frac{40.2}{270} = 0.15$$

USS Suppression Technology

To overcome escalating costs of controlling fugitive emissions from blast furnace casthouses and steelmaking shops, U. S. Steel initiated a series of studies based on work originally done by Dr. Turkdogan and Dr. Kor. This work indicated that iron oxide fumes were generated by the movement of oxygen, as a constituent of air, over molten iron or steel. If the presence of oxygen could be eliminated or minimized, the generation of the red-brown fume could be minimized. Initial efforts to suppress these fumes involved the use of steam, as it was available from the boilers, to create an inert blanket over molten steel during open hearth tapping, as well as for charging hot metal into BOP furnaces. These attempts resulted in varying degrees of success. Various configurations of manifolds, as well as different types of nozzles, were used in an effort to develop a satisfactory blanket over the surface of the metal. During all of these trials, it was noted that one of the more significant parameters appeared to be the quality of the steam being used. Poor quality steam, having some entrained water, was more effective in suppressing fume. To make use of this feature, a means of introducing water into the steam prior to its use was developed. As a result of the various trials and studies conducted in all of the steelmaking shops, a system utilizing a "wet steam" through snow-jet nozzles mounted on the furnace operating floor was utilized successfully for tapping operations in both open hearth and electric furnace shops.

Concurrent with the studies utilizing steam, several attempts were made to utilize other inert gases, primarily nitrogen, as a blanketing medium. These trials proved to be less than satisfactory, and further testing was abandoned.

The use of steam as a suppressant, although technically successful, proved to be metallurgically detrimental in several of the melt shops because of excessive hydrogen pick-up in the steel. To eliminate this problem, a decision was made to attempt to prevent oxidation by consuming the oxygen by means of combustion rather than blanketing with an inert gas. This means of suppression proved to be just as effective as steam blanketing and was applied not only to the tapping of steel from open hearth and electric furnaces, but also to BOP tapping, hot metal transfer and blast furnace casthouses.

1. BLAST FURNACE CASTHOUSE

The U. S. Steel suppression techniques have been successfully applied on iron handling in blast furnace casthouses. This technique utilizes the combustion of natural gas over the iron trough, along the iron runners and spouts, as well as in the iron ladles. The runners are covered with loose-fitting, semi-circular covers which minimize the number of natural gas lances that are required for any iron runner system.

Several types of burners have been used in different locations at various times. At Geneva, where the entire iron runner is suppressed with natural gas, compressed air burners were used to give an effective coverage. However, at other locations, a simple 3/4-inch pipe has been used to provide suppression at the ends of the runner covers and at all openings between segments of the covers. Either compressed air or aspirating burners are used in rings over Kling ladles. Again, simple 3/4-inch pipe lances have proven to be effective when suppressing fumes from torpedo ladles. The choice of burner type is a matter of individual preference. Location of the burners is of far greater importance than the type of burner used. A relocation of as little as two or three inches can mean the difference between compliance and non-compliance. The optimum position of burners at the trough, runners and spouts must be determined for each cast and may have to be changed during the cast if wind conditions change. For this reason, a group of lances or burners mounted on manifolds is the least effective configuration for successful suppression.

Development of runner covers has been an on-going effort. Originally, it was thought that heavy, refractory-lined, tight-sealing covers were required. However, the difficulty in removing these covers for maintenance led to efforts to develop lighter-weight covers. Although various shapes and designs of covers can be found in the various locations because of these trials, the preferred cover is a semi-circular, refractory-lined cover (DF 4329-4). The length of each segment of the cover will be determined by the availability of a crane to remove it or the weight required for removal manually if a crane is not available. Plates are to be welded at each end to reduce the openings, thereby reducing the fuel requirements.

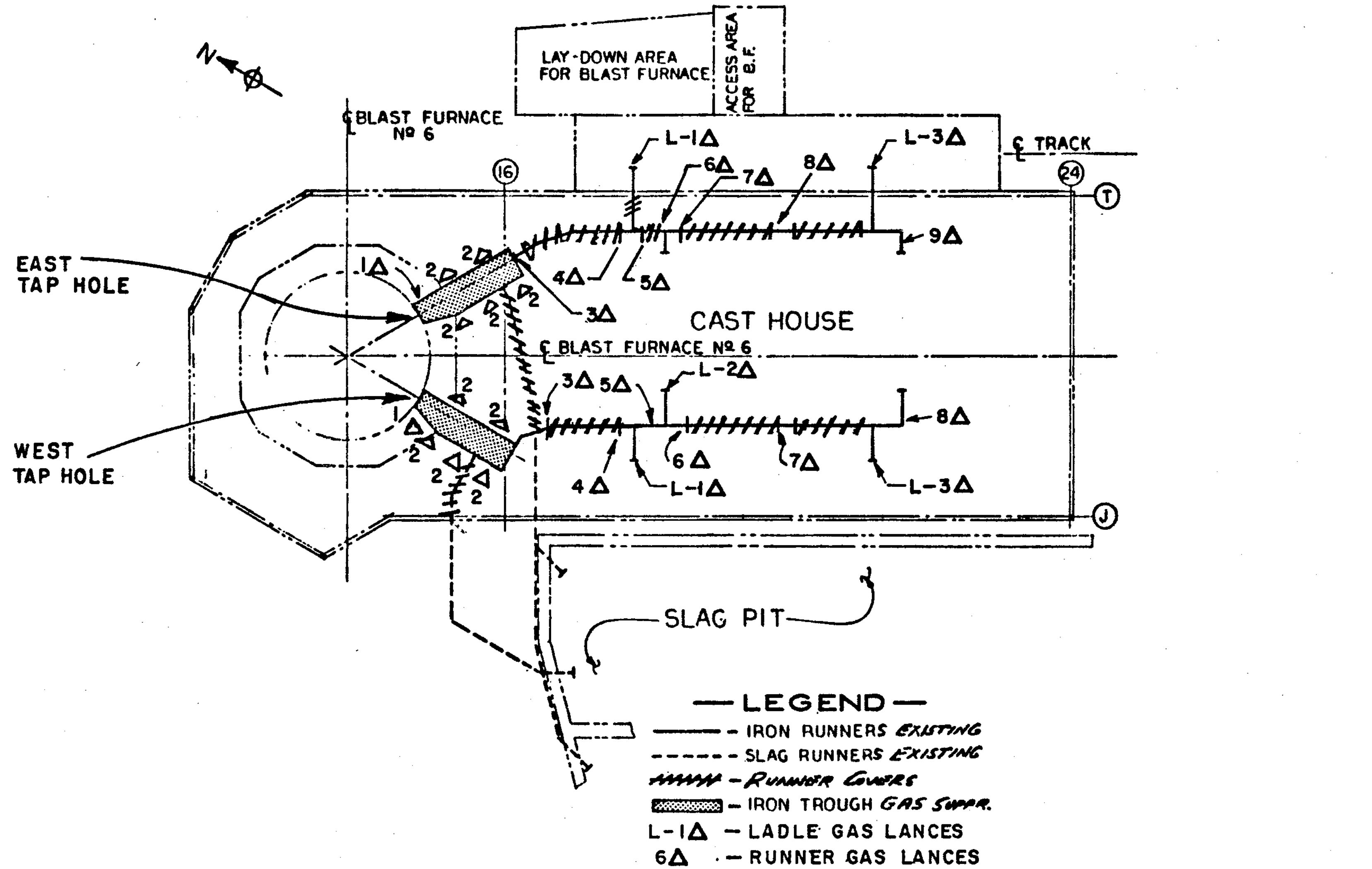
A mixture of water and steam has been used as a suppression medium in torpedo ladles and has proven to be as effective as the combustion of natural gas. No special nozzle is required.

Development of suppression techniques for fumes generated while slag flows has been much slower. At the present time, covers are utilized on the slag runners. Natural gas is burned at the cover opening at gates where slag pots are used. Steam or flame is being used in the slag pots themselves. A study is currently underway to determine the true effectiveness of flame or steam in suppressing slag fumes.

Natural gas usage varies from casthouse to casthouse and is dependent upon the size and configuration of the iron runner system, whether or not slag pots are used, and the duration of the cast. Geneva, which has an extremely long iron runner system without runner covers and uses slag pots and Kling iron ladles, consumes approximately 40,000 cubic feet of gas per cast. Duquesne, which has a dry slag pit and uses iron runner covers, burns approximately 6,000 to 7,000 cubic feet of natural gas per cast.

U. S. Steel has recently submitted to the Regulatory Agencies the results of 40 casts observed in June 1983. Of the total of 52 hours of observations, only six casts did not comply, and 98% of the 13,200 individual opacity readings were less than 20%.

Typical operating plans for three casthouses at three different plants are attached. It will be noted that the common element is that the gas is ignited before a casting operation occurs and continues throughout that operation. In this way, as nearly an inert atmosphere as possible is provided.



FLAME SUPPRESSION
DUQUESNE No. 6 BLAST FURNACE
CAST HOUSE EMISSION CONTROL
7-19-83

DF 4329-1

2. DUQUESNE WORKS NO. 6 BLAST FURNACE CASTHOUSE EMISSION CONTROL

Operating Procedure

East Side

1. Lance and covers will be placed as noted on the attached sketch.

2. After the taphole is opened, the six lances at the trough will be ignited. (These are designated as No. 1 and No. 2 on the sketch.) Also, Lance No. 3, located at the baker dam end of the runner covers, will be ignited.

3. Lances L-7, No. 4, No. 5 and No. 6 will be ignited, in that order, as soon as iron begins to flow.

4. After the first iron ladle is one-half full, Lance L-2 will be ignited.

5. When the second iron ladle is one-half full, Lances No. 7, No. 8, No. 9 and L-3 will be ignited. Air Lance A-1 will be turned on only slightly.

West Side

1. Lance and covers will be placed as noted on the attached sketch.

2. After the taphole is opened, the six lances at the trough will be ignited. (These are designated as No. 1 and No. 2 on the sketch.) Also, Lance No. 3, located at the baker dam end of the runner covers, will be ignited.

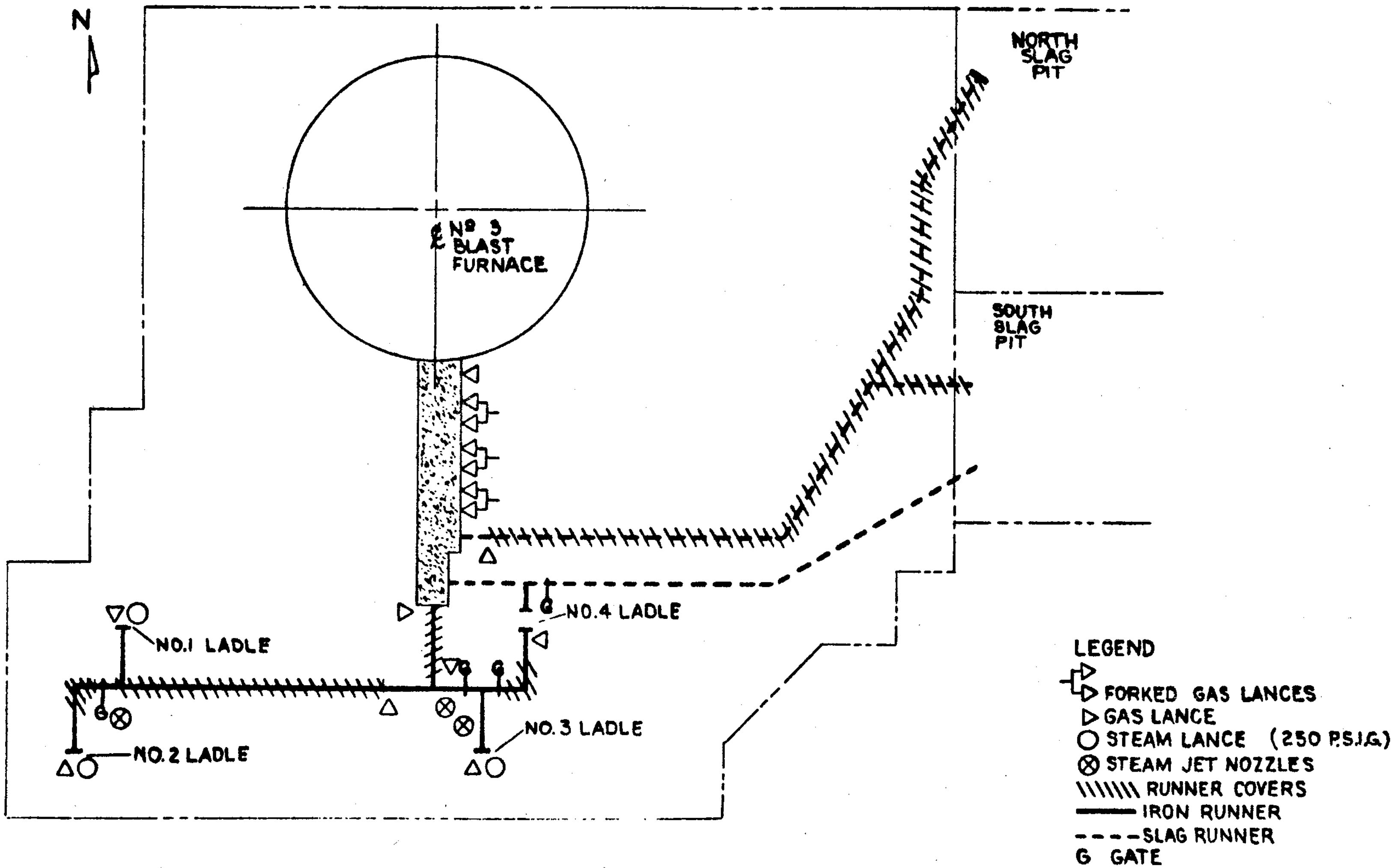
3. Lances L-7, No. 4, No. 5, and No. 6 will be ignited, in that order, as soon as iron begins to flow.

4. After the first iron ladle is one-half full, Lance L-2 will be ignited.

5. When the second iron ladle is one-half full, Lances No. 7, No. 8 and No. 9 will be ignited, along with Air Lance A-1, which will be turned on slightly.

Directions When Either Side is Used

1. All lances will be adjusted to give the most efficient coverage while using the least amount of gas.



FLAME SUPPRESSION

LORAIN WORKS

CAST HOUSE EMISSION CONTROL

7-19-83

DF 4329-2

3. LORAIN WORKS NO. 3 BLAST FURNACE CASTHOUSE EMMISSION CONTROL

Operating Procedure

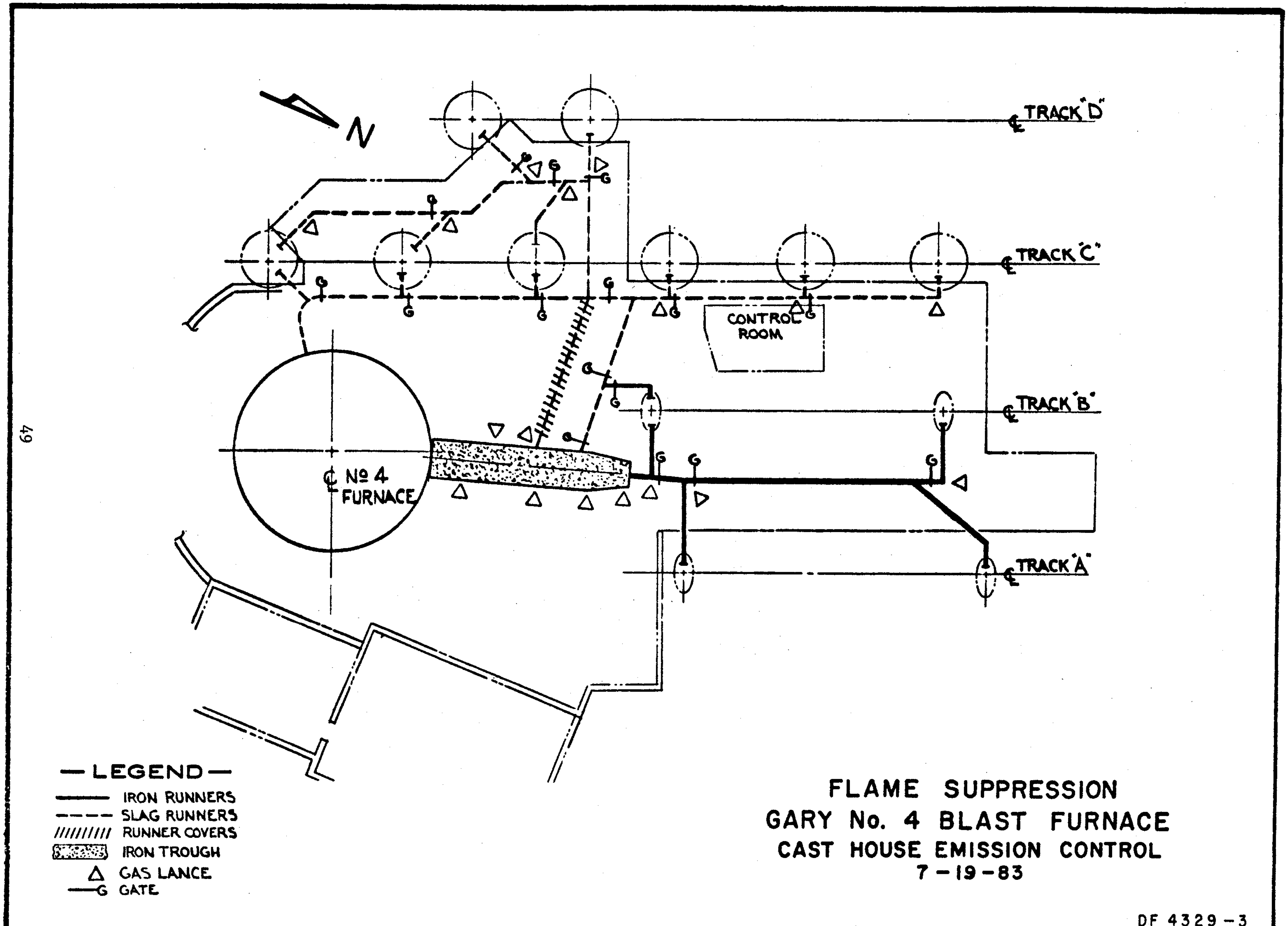
1. Gas lances at the runner spouts shall be maintained in good operating condition at all times and shall be turned on prior to drilling out the taphole.

2. All runner covers shall be in place and properly sealed to prevent any stray emmissions from coming between the covers.

3. Gas lances at the runner "T", where no cover is in place, shall also be turned on before drilling out the taphole.

4. After the drill is swung out of the way, all gas lances on the trough and slag runner will be turned on full.

5. The practice of re-opening the taphole with a small plug of anhydrous clay will be immediately discontinued. If necessary to re-open the taphole, the drill or a burning pipe will be utilized.


N
TRACK "D"
TRACK "C"
TRACK "B"
TRACK "A"
CONTROL ROOM
℄ No 4 FURNACE
G
— LEGEND —
IRON RUNNERS
SLAG RUNNERS
RUNNER COVERS
IRON TROUGH
GAS LANCE
GATE
FLAME SUPPRESSION
GARY No. 4 BLAST FURNACE
CAST HOUSE EMISSION CONTROL
7 – 19 – 83
DF 4329 – 3

4. GARY WORKS NO. 4 BLAST FURNACE CASTHOUSE EMMISSION CONTROL

Operating Procedure

1. Prior to each cast, inspect all lances and covers to be certain that they are in proper position and in good working order.

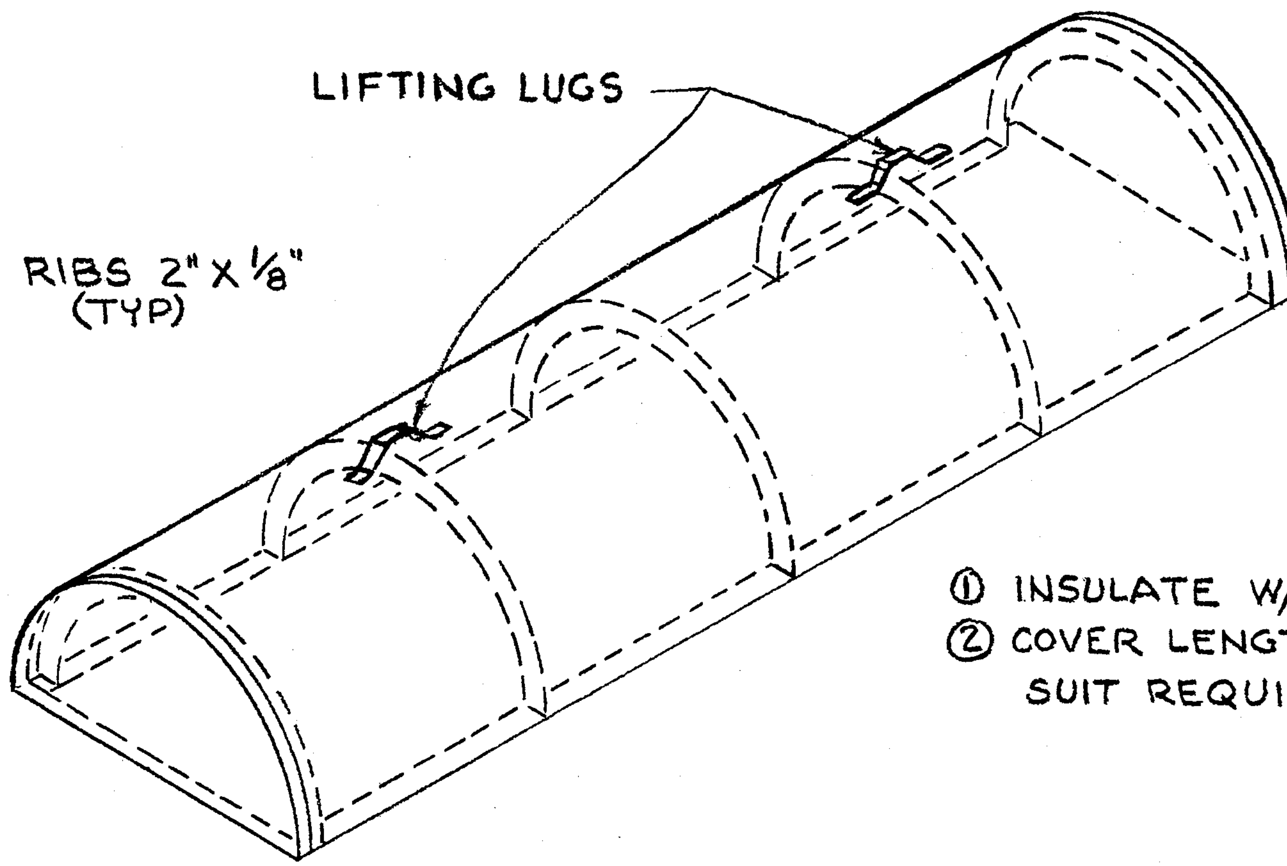
2. Ignite the lance directed at each iron ladle prior to filling. This would allow for the complete elimination of oxygen from the ladle. Turn off when ladle is full.

3. As soon as possible after drill up, and while hot metal is flowing into the trough, activate the gas lances located at the trough.

4. As soon as hot metal is present to ignite the gas, turn on the gas lances located at the iron runner.

5. When slag flow reaches the first slag ladle, activate its gas lance. Deactivate this gas lance when slag flow is diverted to the second ladle. When the slag flows into the second ladle, activate its gas lance. Repeat this procedure for each slag ladle.

6. When all hot metal and slag ceases to flow, deactivate all systems.

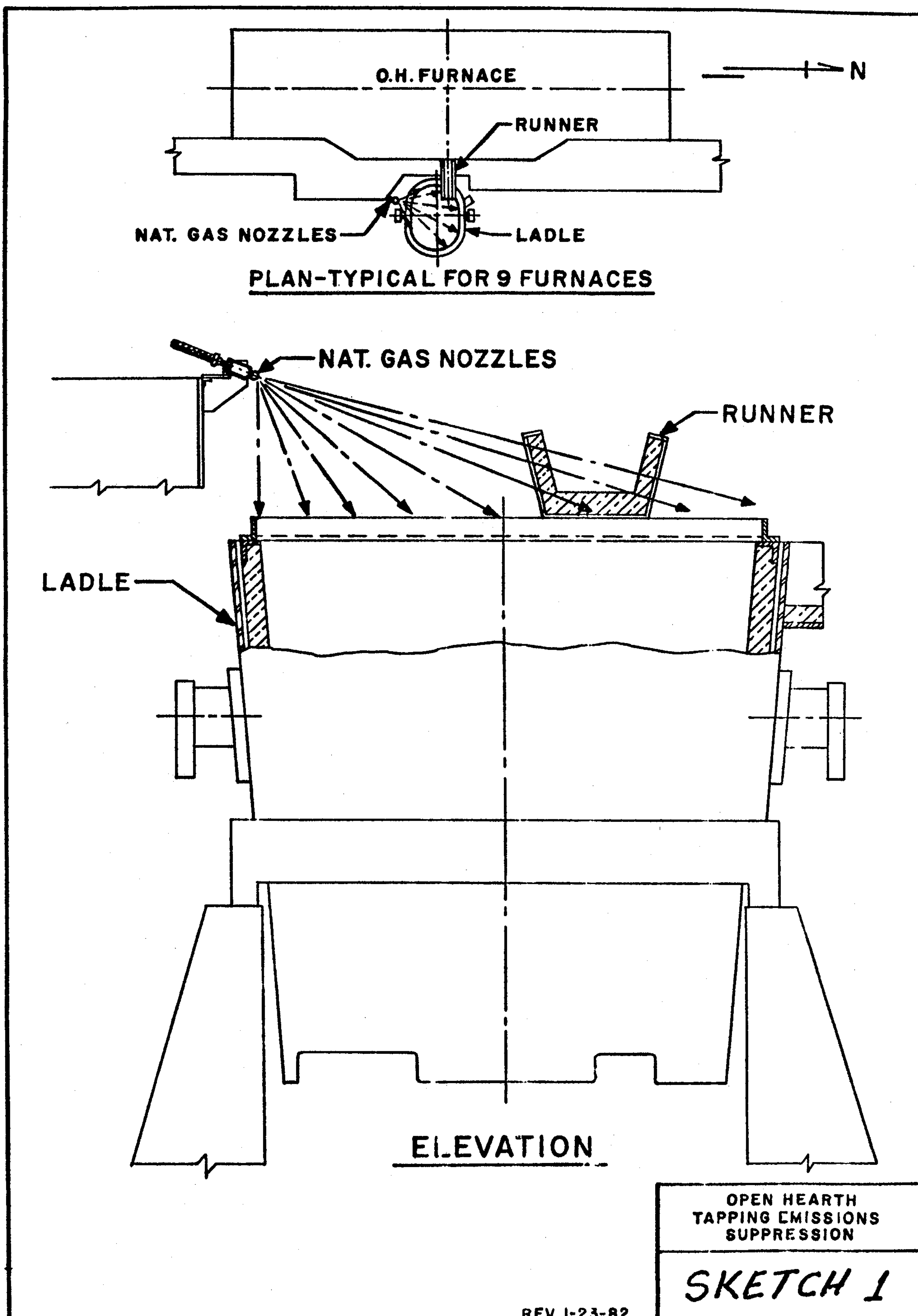


TYPICAL COVER FOR IRON RUNNER

DF4329-4

5. OPEN HEARTH TAPPING

Flame suppression of open hearth tapping fumes is accomplished by burning natural gas over the mouth of the tapping ladle and thereby consuming oxygen and preventing oxygen/molten steel contact. This is accomplished by mounting gas burners on the tapping platform handrail, above and to the side of the ladle. Attached Sketch No. 1 indicates the approximate location of these burners. However, the final position and angles of burners for any installation must be determined on an individual basis, depending on the geometry of the furnace, ladle and ladle pit. Ignition controls for the system are located at a positon where an operator is located to observe the tap and initiate ladle additions. Although an ignition system may be used, operational experience has indicated that it is not necessary. The molten steel provides ignition for the natural gas. The system is initiated after the taphole has been opened and molten steel begins to flow from the spout. This operation continues until the tap is complete. Effective control of fumes has been attained by using 65 psi natural gas at the rate of approximately 110,000 standard cubic feet per hour.

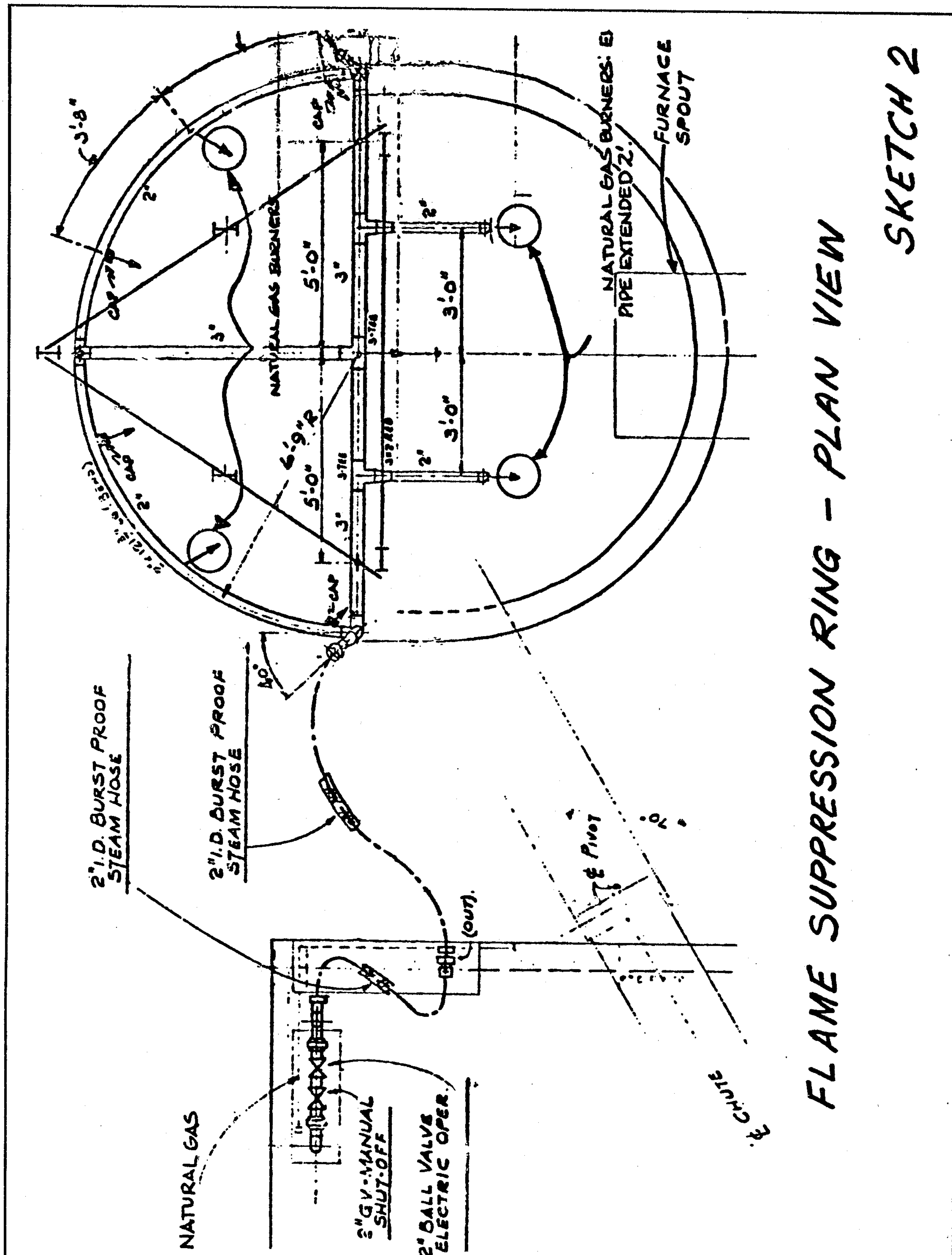

O.H. FURNACE
N
RUNNER
NAT. GAS NOZZLES
LADLE
PLAN-TYPICAL FOR 9 FURNACES
NAT. GAS NOZZLES
RUNNER
LADLE
ELEVATION
OPEN HEARTH
TAPPING EMISSIONS
SUPPRESSION
SKETCH 1
REV. 1-23-82

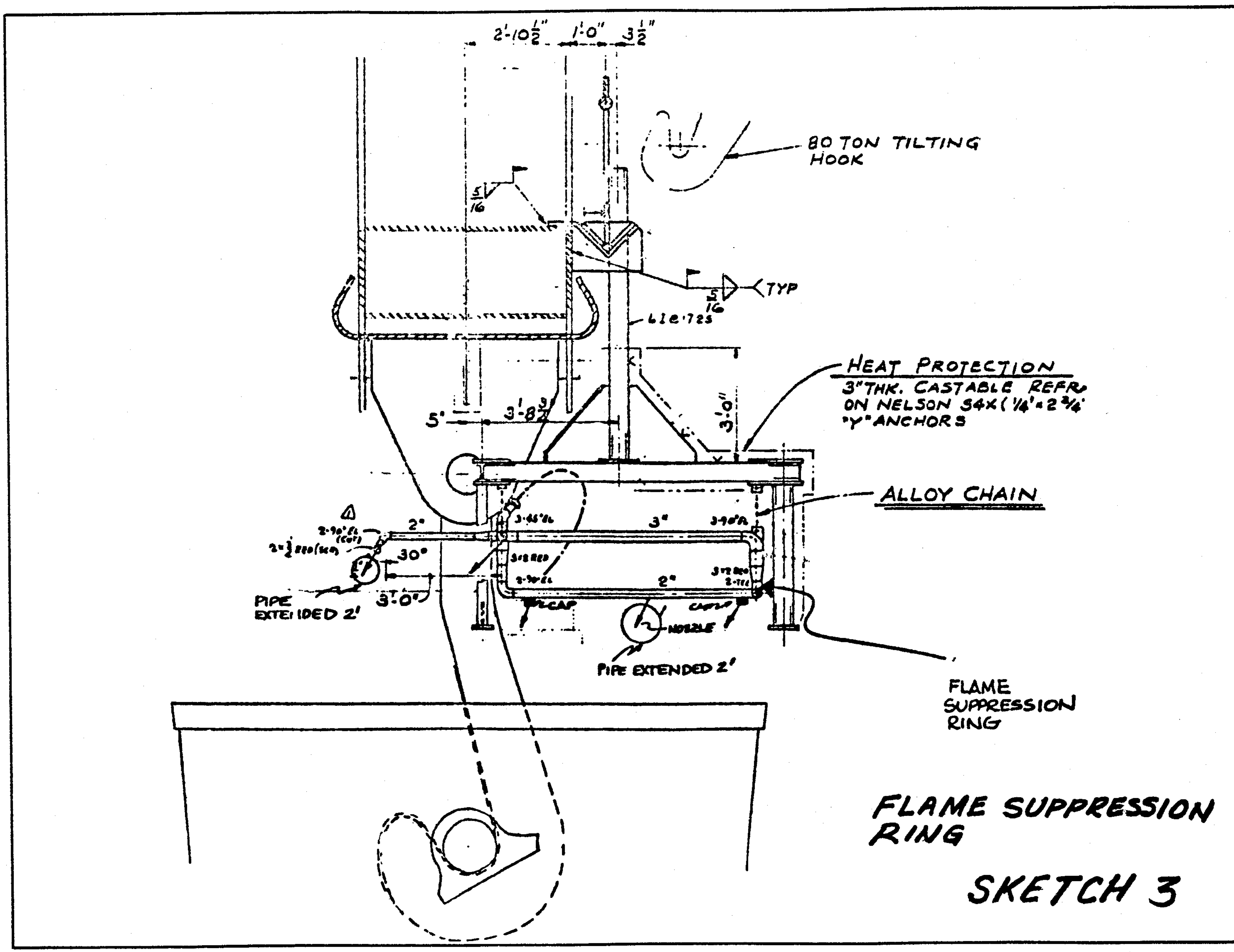
6. ELECTRIC FURNACE TAPPING

Flame suppression is being used to control electric furnace tapping emissions. There have been two configurations of burner systems utilized to effect this suppression. The first system consists of a suppression ring which is suspended directly over the ladle and is carried by the auxiliary hook on the pit crane. This ring has four burners, as shown on the accompanying Sketches, Nos. 2 and 3, which direct the flame into the ladle. Ignition of the natural gas occurs when the molten steel begins to flow from the spout.

A second system involves the use of burners permanently mounted on the furnace platform adjacent to the pouring spout. The burners are positioned in such a manner that some natural gas is being burned in the ladle throughout the tap as the furnace platform rotates and the angle between it and the ladle changes (Sketch No. 4). The required number and final positions of the burners can only be determined after a complete analysis of the facility on which they are to be installed. The geometry of the furnace platform, the ladle, and the ladle pit will be the determining factors for this design.

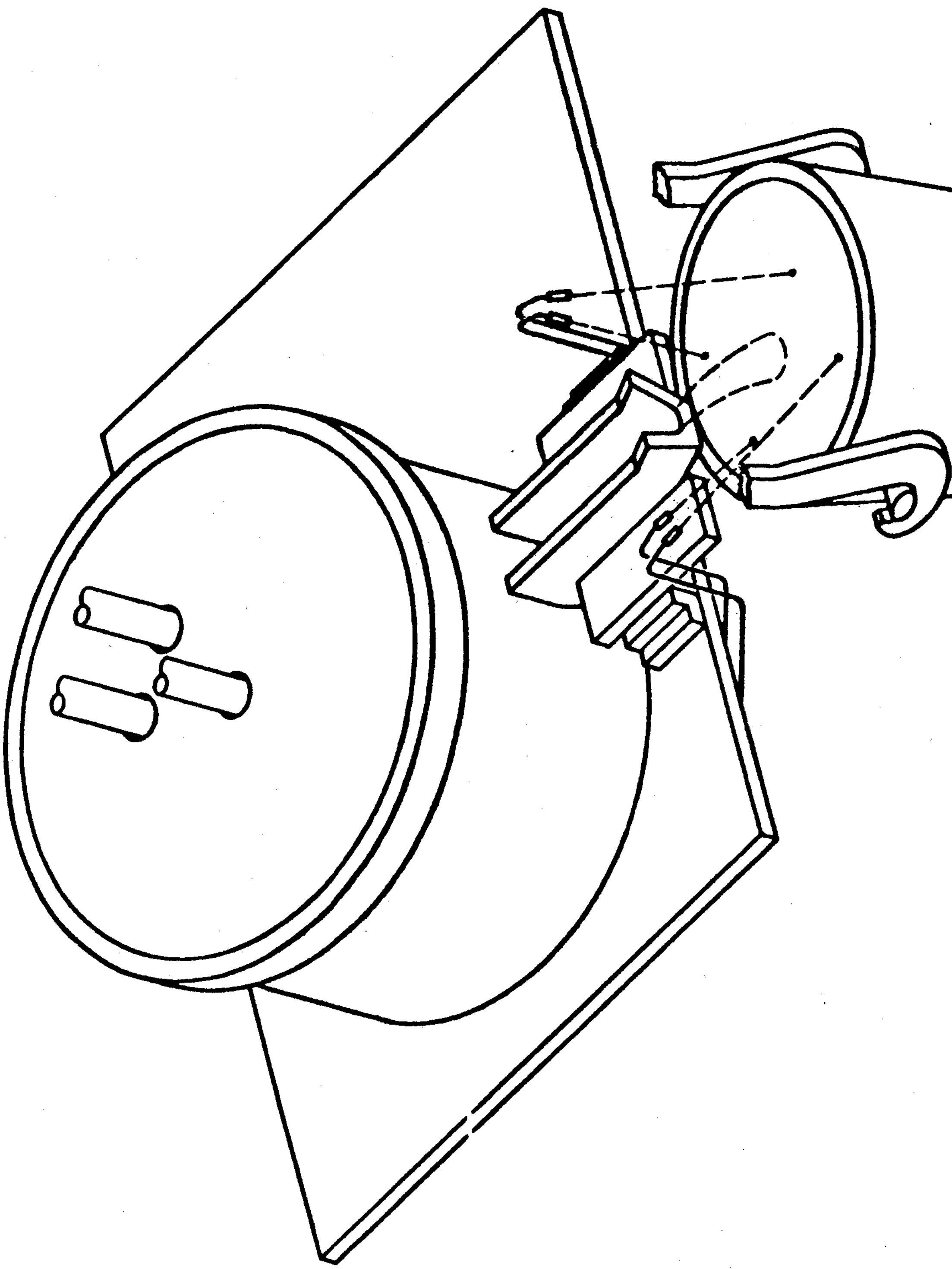
Operating experience with both of these systems indicates that between 650 and 750 cubic feet per minute of 60 psi natural gas is required for effective control of the fumes. The system controls in both cases are located in a position from which the operator observes the tap and initiates ladle additions. The systems are actuated when the furnace is tapped and the molten steel provides the ignition. Gas is burned over the ladle until the tap is completed.


FLAME SUPPRESSION RING - PLAN VIEW
SKETCH 2
NATURAL GAS BURNERS:
PIPE EXTENDED 2'
FURNACE SPOUT
3'-8"
NATURAL GAS BURNERS
5'-0"
3'-0"
6'-9" R
CAP
2" I.D. BURST PROOF STEAM HOSE
2" I.D. BURST PROOF STEAM HOSE
(OUT)
℄ PIVOT
℄ CHUTE
NATURAL GAS
2" G.V. MANUAL SHUT-OFF
2" BALL VALVE ELECTRIC OPER.



FLAME SUPPRESSION RING

SKETCH 3



ELECTRIC FURNACE
FLAME SUPPRESSION SYSTEM

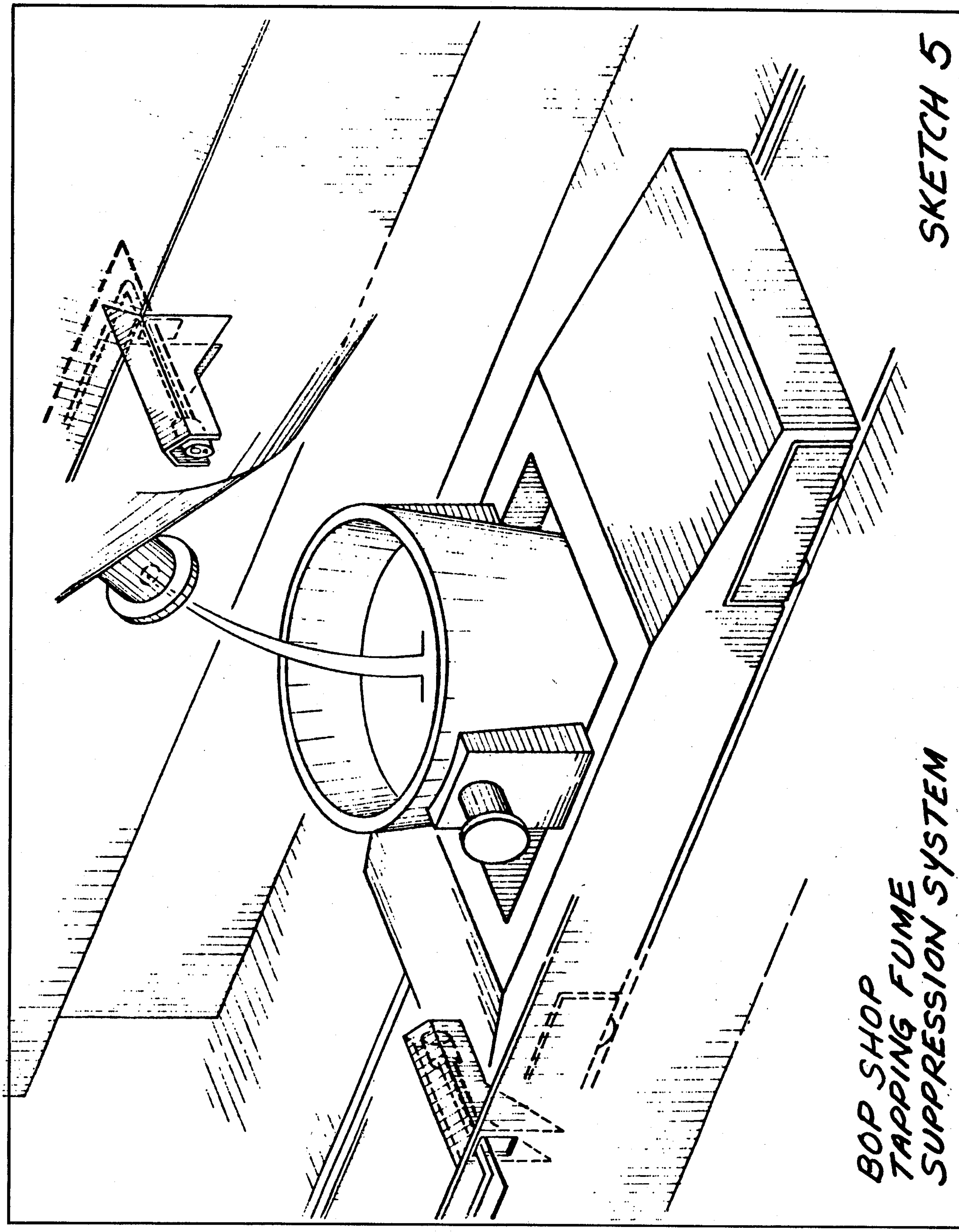
SKETCH 4

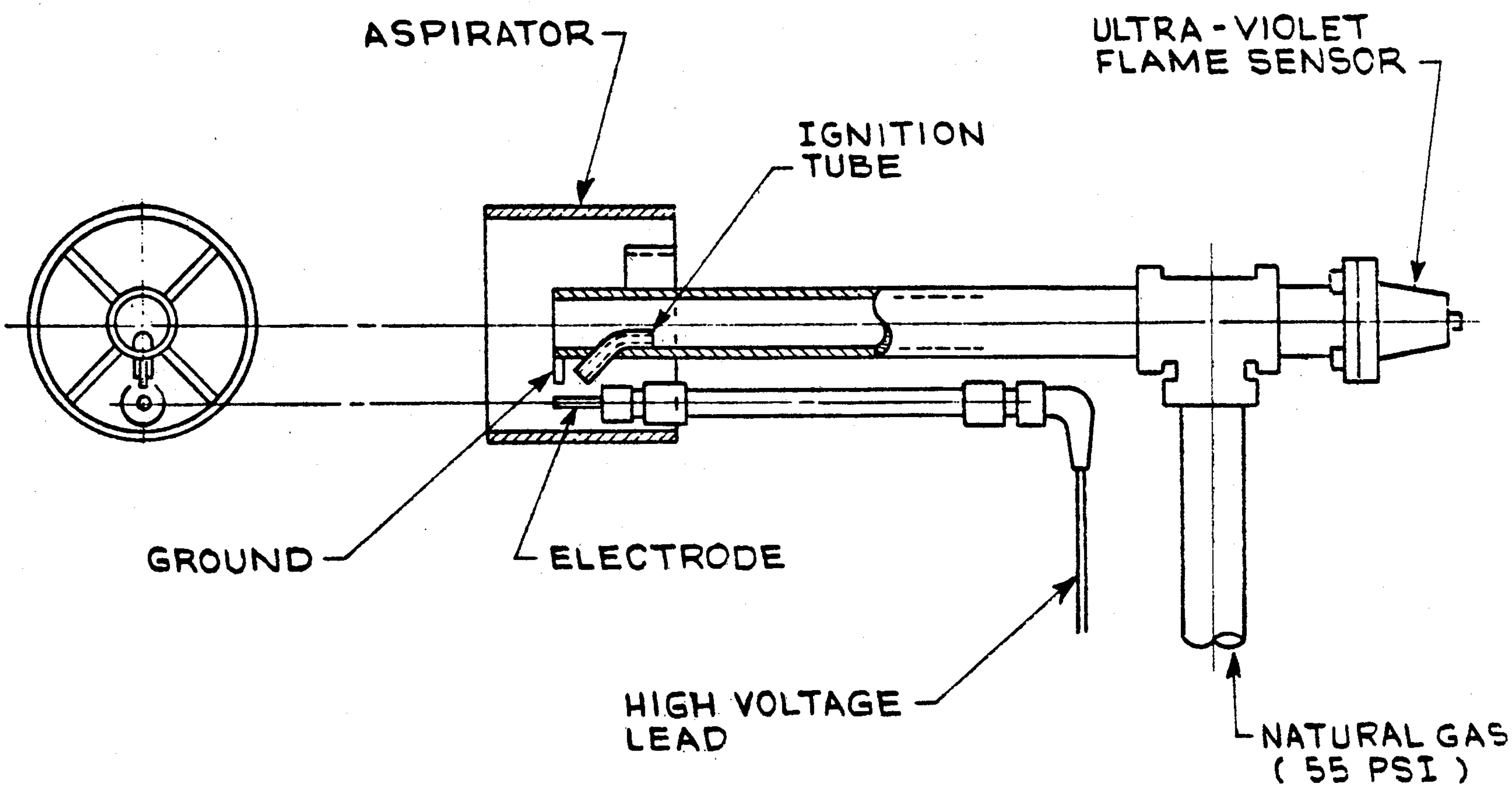
7. BOP TAPPING

Suppression of fumes generated while tapping a BOP furnace is accomplished through the combustion of natural gas in the vicinity of the flowing steel. As can be seen in the attached Sketch No. 5, a pair of burners, one on each side of the vessel, are directed into the tapping ladle. The natural gas is ignited just before the metal starts to flow to purge the ladle of oxygen.

Aspirating burners have been successfully used in this application and consume 60 psi natural gas at the rate of approximately 700 cubic feet per minute.

Due to the relative inaccessibility of the burners, a good ignition and flame sensing system is necessary. Sketch No. 6 is an example of one such system.


SKETCH 5
BOP SHOP
TAPPING FUME
SUPPRESSION SYSTEM



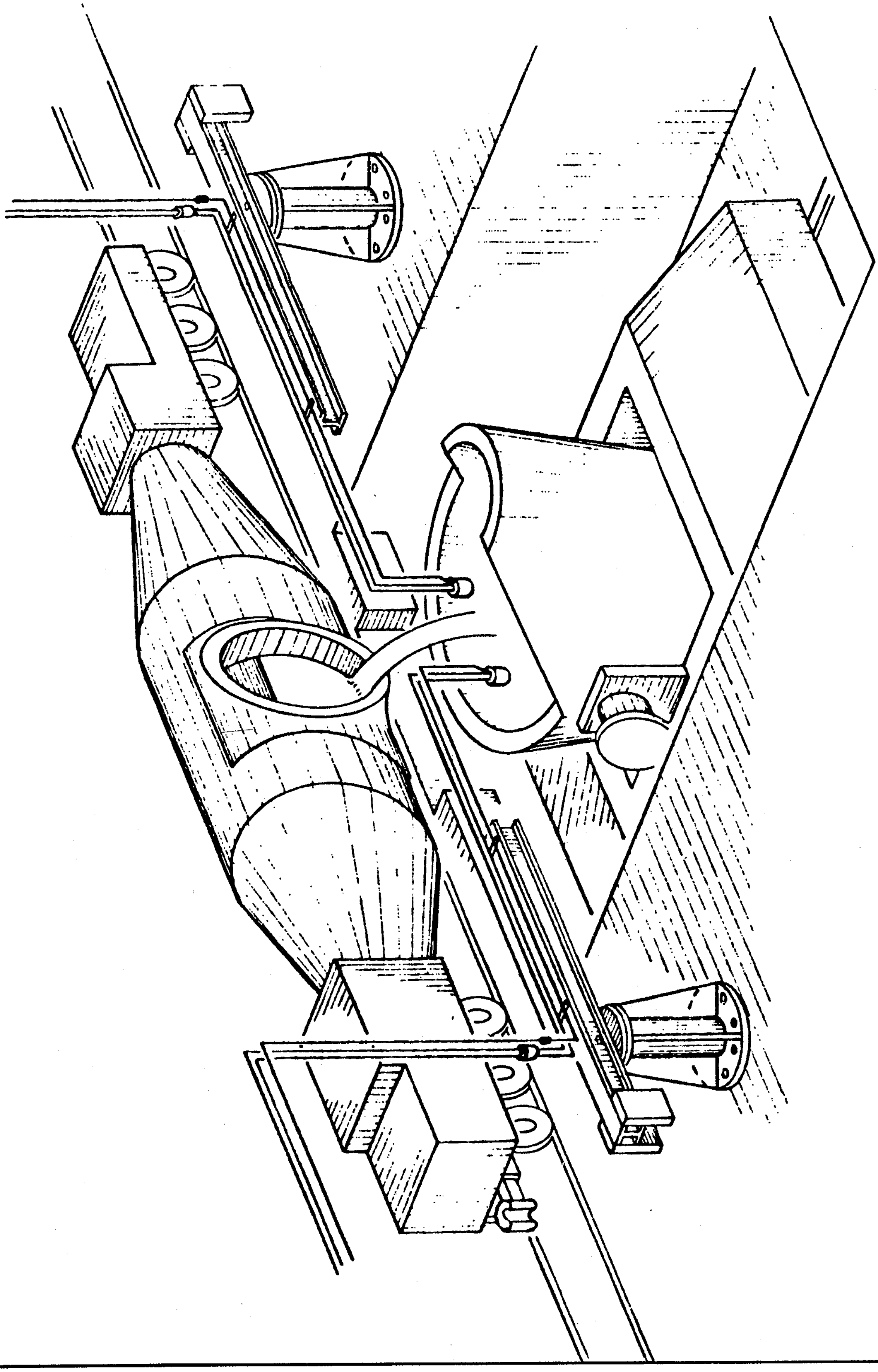
BOP SHOP
TAPPING FUME SUPPRESSION SYSTEM
BURNER, IGNITION & FLAME SENSOR

SKETCH 6

8. HOT METAL TRANSFER

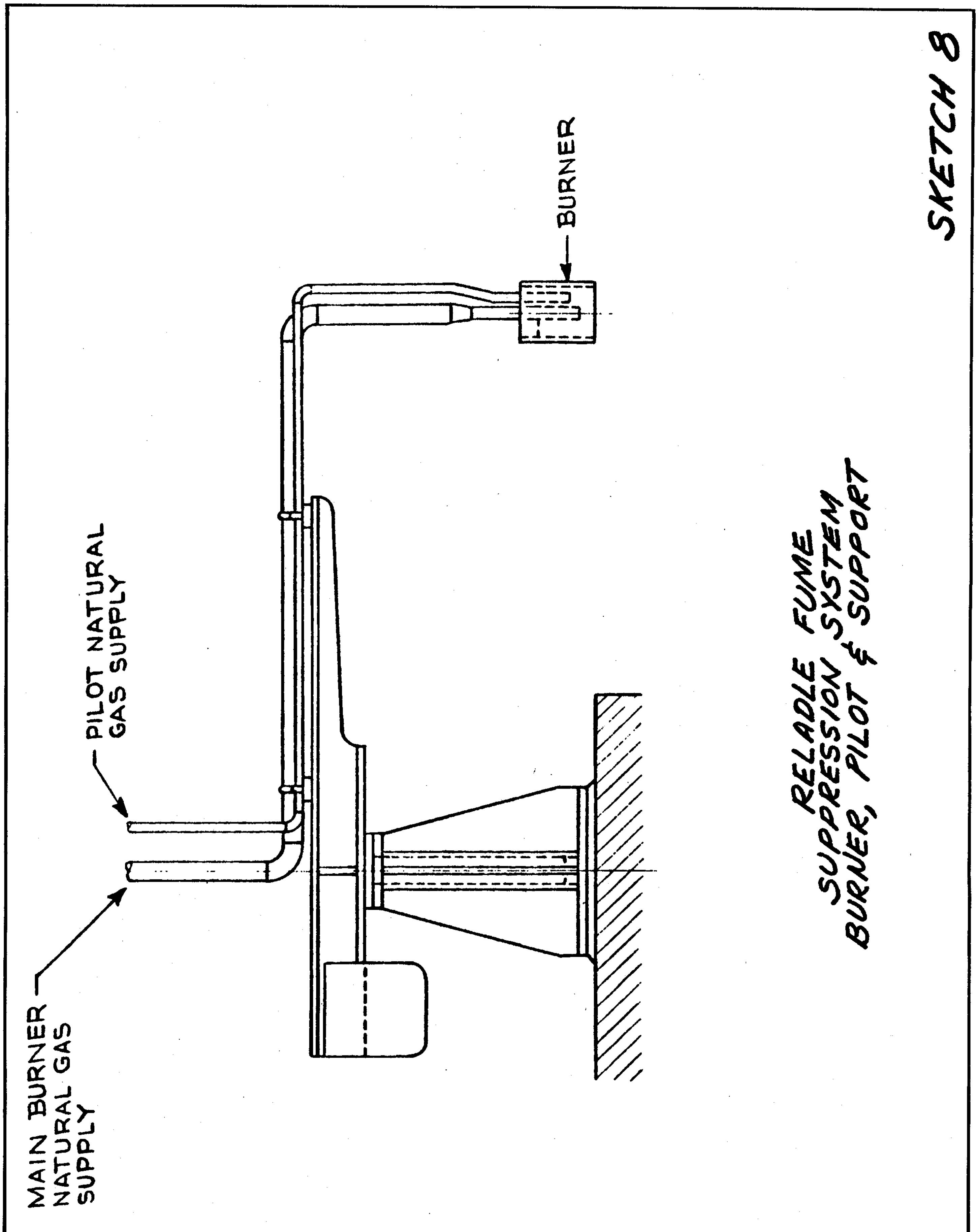
Transfer of iron from torpedo ladles to transfer or charging ladles, as well as into and out of hot metal mixers, is also a source of heavy fume generation where supression through the combustion of natural gas has been very successful. Aspirating burners are positioned over the mouth of the receiving vessel so that any oxygen present in the vessel is consumed, resulting in an inert atmosphere (Sketches Nos. 7, 8, 9, 10 and 11). In all cases, the burners are ignited between 15 and 30 seconds before the transfer is started and combustion continues until the pour has been completed.

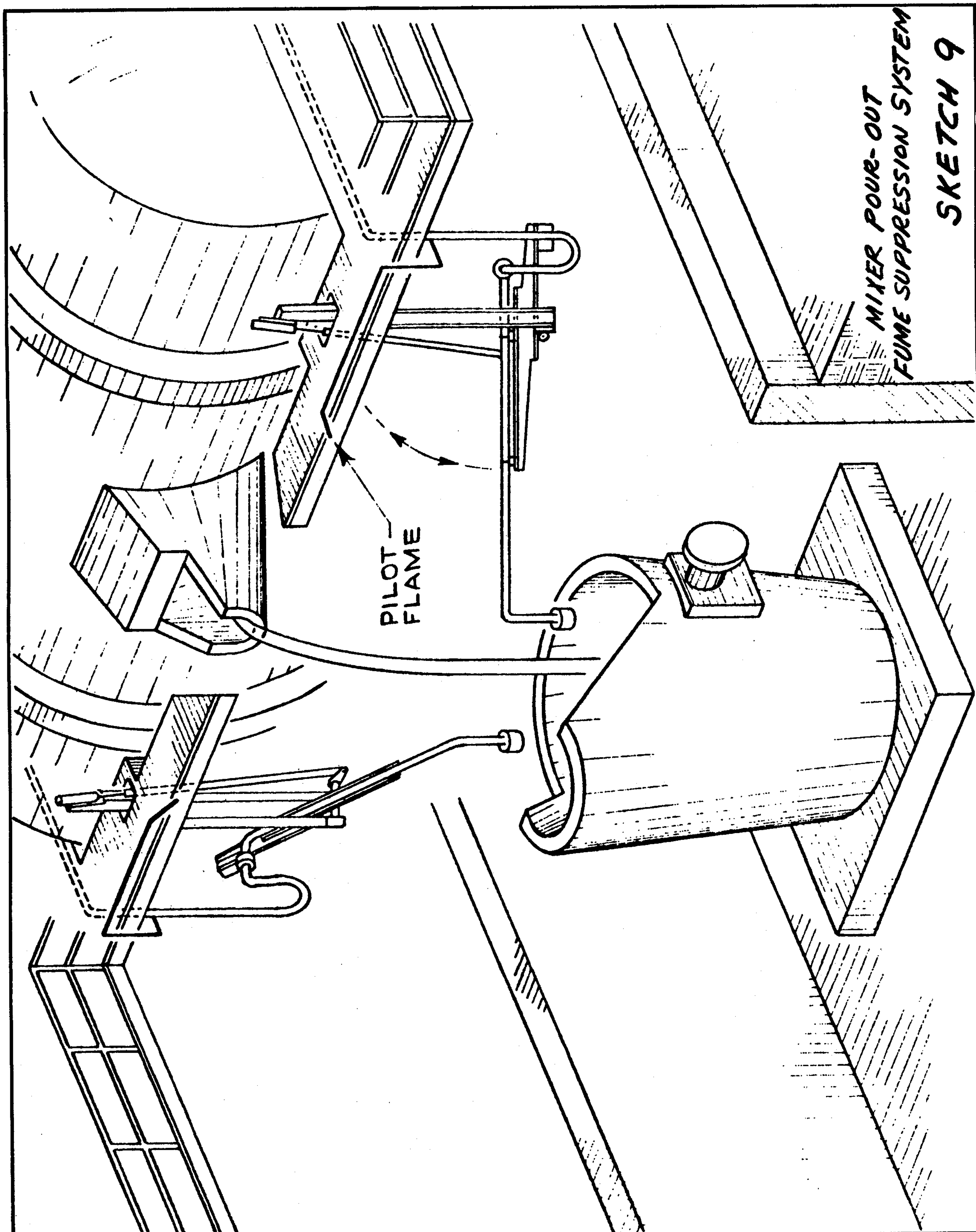
Natural gas at pressures varying from 15 to 55 psi, depending on the location, is consumed at the rate of approximately 500 to 1000 cubic feet per transfer.

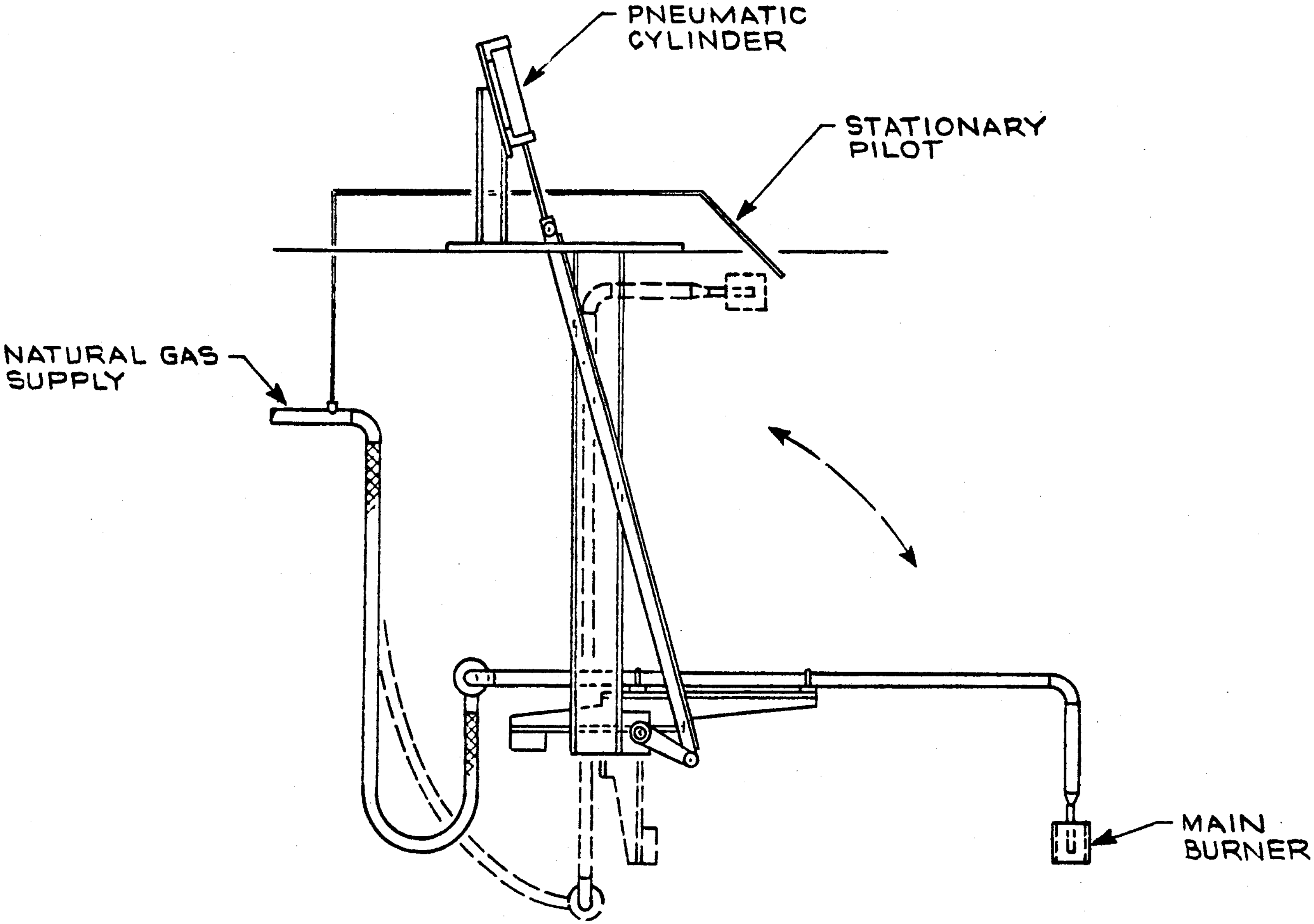


SKETCH 7

RELADLE FUME SUPPRESSION SYSTEM

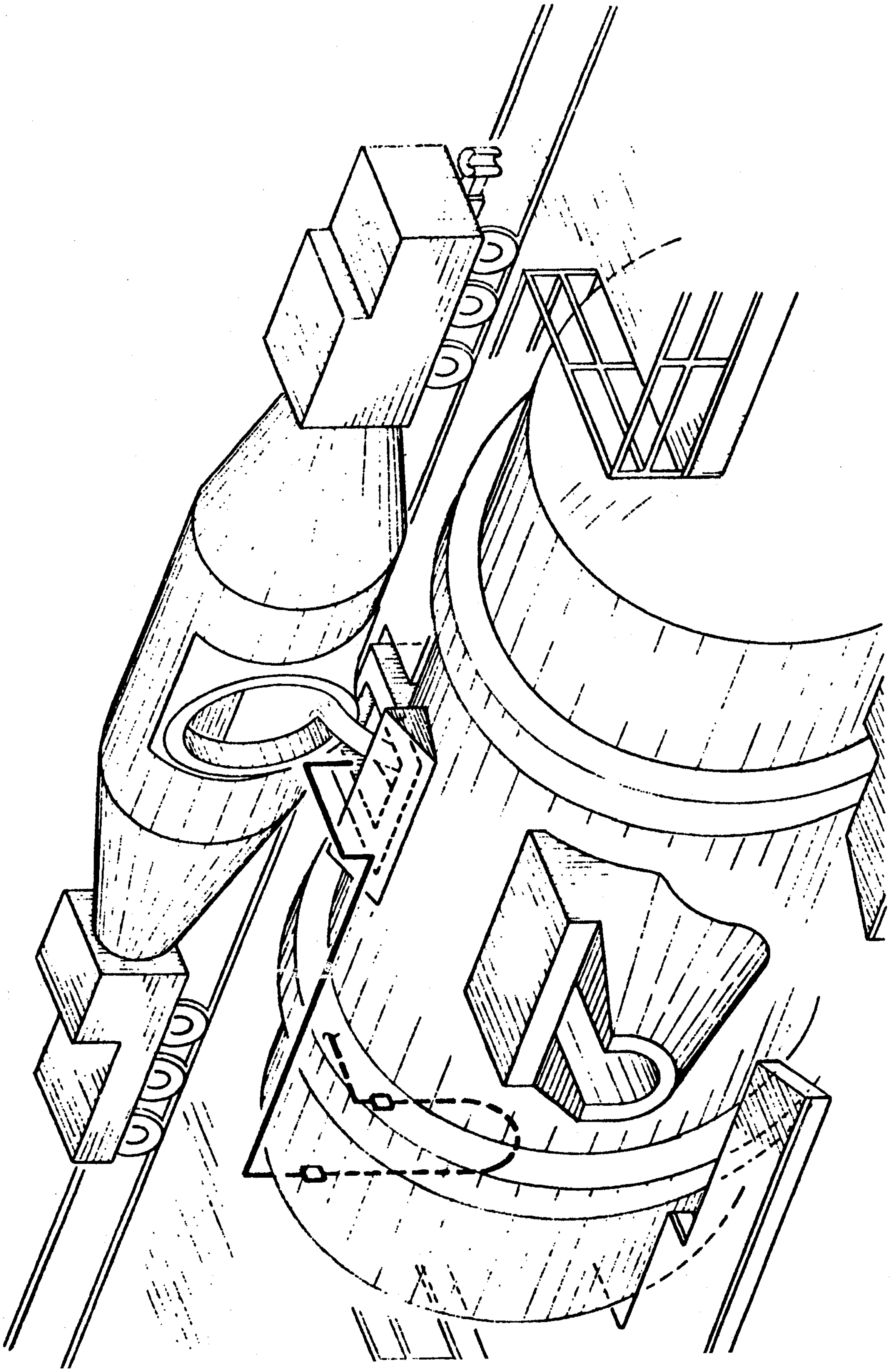

SKETCH 8
BURNER
PILOT NATURAL GAS SUPPLY
MAIN BURNER NATURAL GAS SUPPLY
RELADLE FUME SUPPRESSION SYSTEM BURNER, PILOT & SUPPORT


PILOT FLAME
MIXER POUR-OUT
FUME SUPPRESSION SYSTEM
SKETCH 9



MIXER POUR-OUT
FUME SUPPRESSION SYSTEM
BURNER, PILOT & POSITIONING MECHANISM

SKETCH 10



SKETCH 11

MIXER INLET BASKET
FUME SUPPRESSION SYSTEM

Table of Contents—Section 2

Emission Control Techniques

Control of Emissions from Coke Oven Doors

DESIGN AND OPERATIONAL GUIDELINES

1. INTRODUCTION

As part of the efforts to meet environmental-control standards for coke oven batteries, U. S. Steel initiated an extensive coke-oven-door research program in 1975, which included both analytical and experimental work. This program involved a detailed analysis of the sources of door emissions, the development of possible solutions to the problems, and an evaluation of the solutions adopted. This manual summarizes the design features and operating procedures developed, which have proven successful in minimizing the emissions from the doors of both Koppers and Wilputte-type batteries.

A door designated USS-2 has been designed primarily for use on new and existing Koppers-type batteries, and a door designated USS-1 has been designed primarily for use on new and existing Wilputte-type batteries. It should be recognized, however, that these door systems can be custom fit to any type battery. Besides the design features, this manual describes step-by-step guidelines for the proper assembly, inspection, and maintenance of the various door components. Procedures are also presented for proper door installation, seal adjustment, and door spotting. Door and jamb cleaning requirements, door-leakage troubleshooting, seal reconditioning, and plug refractories are also discussed.

These guidelines must be followed to achieve maximum door-sealing performance.

1.1 DOOR TECHNOLOGY DEVELOPED

A major conclusion of the U. S. Steel door research work and the work by others is that the problem of sealing coke-oven doors is very complex because of the many design and operational elements in the coke-oven-door system that can fail in the hot, carbonaceous environment of the coke battery, Table 1-1. These elements can be considered to be links in a chain, each of which is essential to form an effective door system; if one link in the chain is broken, the door system will fail. Unfortunately, there are many factors that can break the links. The effective door-system chain is depicted very simply in Figure 1-1, where the only links shown are a good jamb, a good seal, and proper door placement. Adjacent to the links in Figure 1-1 are listed some of the many factors that can destroy the links and cause the failure of an effective door system. Initial poor quality of door components, heat distortion, handling damage, improper adjustment, carbon buildup, and insufficient latch force are examples of adverse factors that may cause the failure of an effective door system. A conscientious and continuous effort is required by all the coke-plant personnel to maintain control over all these factors.

1.2 APPLICATION OF DOOR TECHNOLOGY AT CLAIRTON WORKS

Possible solutions for reducing coke-oven door emissions were based on the results of research programs conducted at various U. S. Steel plants. Several design and operational improvements that were developed were incorporated in the modified Koppers doors at Clairton Works. Significant reduction in door emissions was achieved as shown in Figure 1-2. Because many Koppers doors were scheduled for replacement because of age, a new door was designed for Koppers-type batteries to incorporate all the improvements developed to date. These doors, designated USS-2, have performed well in reducing emissions. Many Wilputte doors were also scheduled for replacement because of age, and therefore a new door was designed for Wilputte-type batteries to incorporate all the improvements developed to date. These new doors, designated the USS-1 doors, were recommended for use on all Wilputte-type batteries.

1.3 OPERATIONAL GUIDELINES

This operating manual provides design descriptions and guidelines for the assembly, installation, adjustment, spotting, handling, cleaning, troubleshooting, and reconditioning of the USS-2 and USS-1 doors. If these guidelines are followed, door emissions can be controlled sufficiently to meet the latest stringent government standards on door emissions.

(TABLE 1-1)

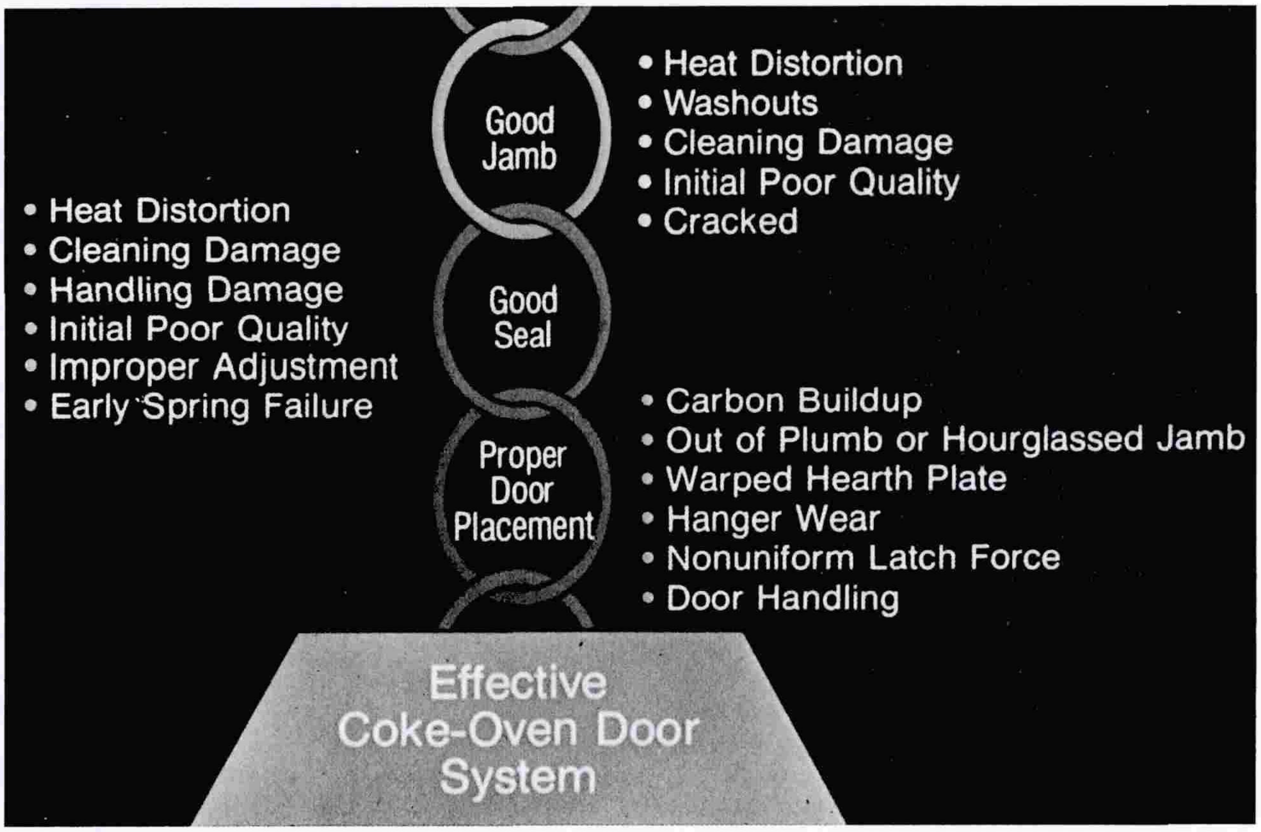
COKE-OVEN-DOOR SYSTEM DESIGN AND OPERATIONAL ELEMENTS

Design Elements

1. Door frame
2. Latches
3. Lifting lugs
4. Guide blocks
5. Seal-loading system
6. Door hanger
7. Seal
8. Plug
9. Plug-retainer system
10. Leveler Door
11. Jamb
12. Jamb support
13. Latch hooks
14. Door-weight support
15. Door-handling equipment
16. Buckstay
17. Hearth plate
18. Oven walls and roof
19. Plug-to-oven wall
20. Plug-to-roof clearance
21. Plug-to-floor clearance
22. Guide-to-jamb clearance
23. Seal-to-latch hook clearance
24. Gas channel area
25. Standpipe opening
26. Oven roof-to-coal charge-surface clearance

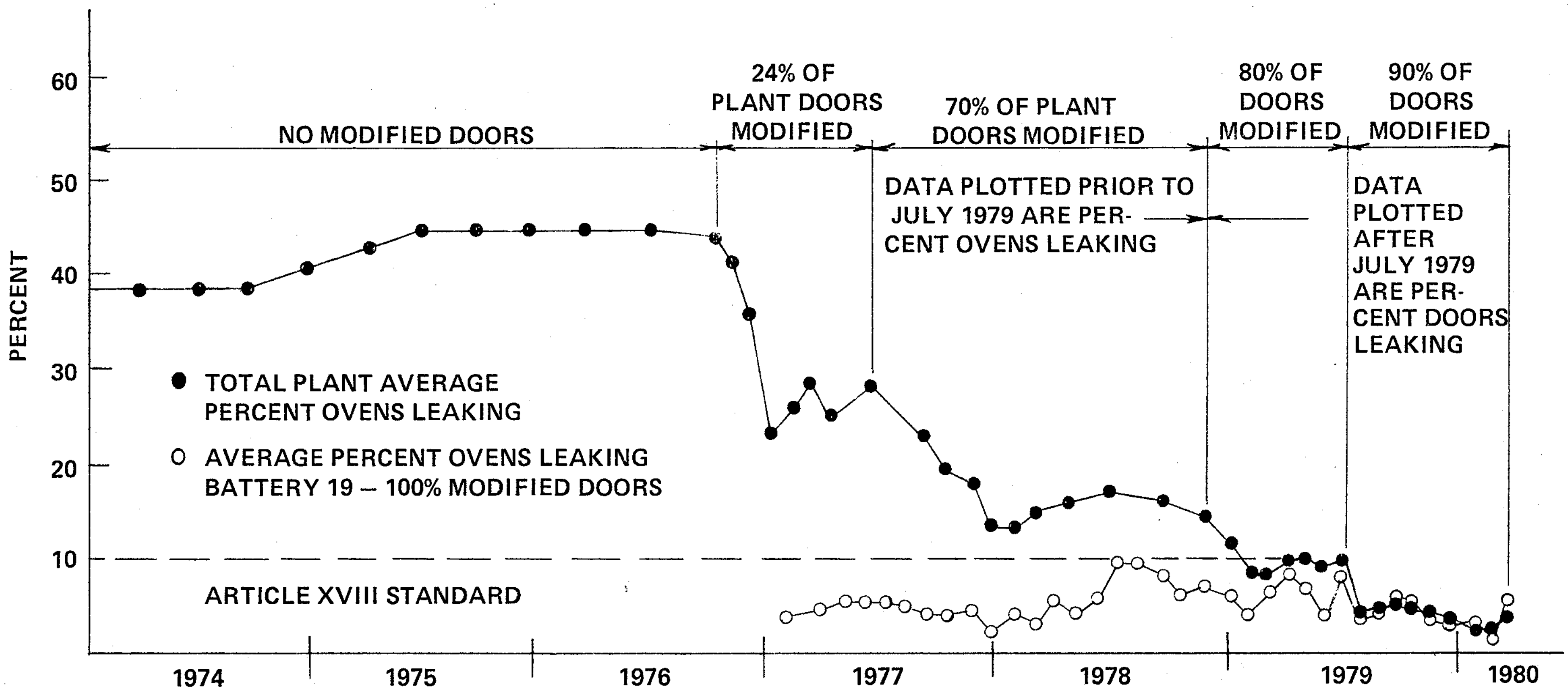
Operational Elements

1. Door manufacture and assembly
2. New door installation on oven
3. Seal adjustment
4. Door handling: spotting, removal, placement, and latching
5. Door and jamb cleaning
6. Door-leakage troubleshooting and correction
7. Door reconditioning
8. Quality control of replacement parts
9. Latch lubrication



CHAINLIKE CONDITIONS REQUIRED TO ACHIEVE EFFECTIVE COKE-OVEN-DOOR SYSTEM AND THE FACTORS WHICH CAN BREAK THE CHAIN

Figure 1-1



TOTAL PLANT AVERAGE PERCENT OVENS LEAKING VERSUS TIME – CLAIRTON WORKS

Figure 1-2

2. DESCRIPTION OF USS-2 AND USS-1 DOORS

Coke-oven doors have been designed for both Koppers-type and Wilputte-type batteries, which incorporate the latest improvements in door technology developed by U. S. Steel for effective sealing. A description of the various components of the new doors (designated USS-2 for Koppers-type doors and USS-1 for Wilputte-type doors) is presented in the following sections.

2.1 USS-2 (KOPPERS) DOOR FRAME

The USS-2 door frame is shown in cross section in Figures 2-1, 2-2 and 2-3 and is manufactured from A319T grey cast iron. The door is supported from its sides near the top latch on self-lubricating rollers. There are two steel bars mounted in slots in the door frame which serve as door lifting lugs.

A series of integral projections are cast around the outside perimeter of the door frame for supporting spring-loaded plungers to provide localized loading to the door seal. Figure 2-4 shows an enlarged section through the spring plunger assembly which is designed as a module for ease of replacement. There are a total of 48 plungers for the coke side door and 48 plungers for the pusher side door. The plunger springs are manufactured from 17-7 stainless steel with a service temperature of 625°F (496°C) and are each capable of providing up to 1500 lbs. (6.7 kN) of force. A sight pin is provided for visual observation of the spring load.

A continuous pad is cast as an integral part of the door frame for supporting the door seal and plug. This design ensures a uniform seal seat, minimizes heat transfer to the door frame and permits seal straightening on the door without the necessity of removing the plug.

The section modulus and the moment of inertia in bending of the door frame at the latch areas between the plungers and without the appendages is 80 in.^{3} (1.0 x 10^6 mm^3) and 399 in.^{4} (11.6 x 10^7 mm^4), respectively.

2.2 USS-1 (WILPUTTE) DOOR FRAME

The USS-1 door frame is shown in cross section in Figures 2-5, 2-6, and 2-7 and is manufactured from MC10 x 21.9, A36 structural steel channels welded into an open frame by top and bottom steel tie plates. The door is supported on its bottom in a manner very similar to the support for conventional Wilputte doors. There are two cast-steel lifting lugs welded between the door-frame channels.

A series of steel castings are welded around the outside perimeter of the door frame for supporting spring-loaded plungers to provide localized loading to the door seal. Figure 2-8 shows an enlarged section through the spring-plunger assembly, which is designed as a module for ease of replacement. There are a total of

42 plungers for the coke-side door and 44 plungers for the pusher-side door. The plunger springs are manufactured from 17-7 (AISI Type 301) stainless steel with a service temperature of 625°F (496°C) and are each capable of providing up to 1500 lb. (6.7 kN) of force. A sight pin is provided for visual observation of the spring load.

A continuous plug-mounting plate is welded to the forward portion of the door frame for supporting the door seal and plug. This design ensures a uniform seal seat, minimizes heat transfer to the main door frame, and permits seal straightening on the door without the necessity of removing the plug.

The section modulus of the door frame at the latch areas between the plungers and without the appendages is 39.4 $in.^3$ (6.5×10^5 mm^3). The anticipated maximum bending stress is 4.8 ksi (33 MPa).

2.3 DOOR LATCHES

The latching system is an improved, conventional screw type to be compatible with conventional door machinery. The latch screws are supported with a nut bracket assembly bolted to the door frame. Each latch is supported on a combination radial-thrust bearing with a capacity of 88,000 pounds (391 kN) thrust and 35,000 pounds (156 kN) radial load. This bearing will accommodate angular misalignment of the latch up to 1/2 inch (12.7 mm) at the latch ends and still permit all of the latch force to be transmitted uniformly to the door seal. Lubrication holes are provided for both the bearings and the latch screws and grease seals are provided for the bearings. The bearings are retained to the latches with a steel keeper plate bolted to the latch body.

2.4 LEVELER DOORS

2.4.1 Figure 2-9 shows a general arrangement of the USS-2 spring-loaded leveler door which is supported to the main door frame by a conventional dual hinge and cam lock mechanism and the door arm is designed for automatic door-opening machinery. The leveler door is manufactured from nodular ferritic cast iron (NFCI) and the thickness at the hub is somewhat greater than conventional leveler doors to reduce anticipated high thermal stresses.

2.4.2 To ensure a uniform distribution of the spring load to the door seal edge, a pair of mating spherical washers is provided between the door and spring.

2.4.3 The system is designed for a spring load of 2700 lbs. (12.1 kN) when latched, which is equivalent to 51.9 lbs. (0.23 kN) per lineal inch of the perimeter of the door sealing edge. A shim pack is provided to accommodate variations in spring height and manufacturing inaccuracies.

2.4.4 A sight pin and self-locking nut are provided to visually observe the spring load when the door is latched.

2.4.5 A thermal insulating gasket is provided between the spherical washers and the door to reduce the heat transfer to the spring.

2.4.6 The leveler door seal edge is designed as an integral part of the door body for ruggedness and is also tapered adequately for cutting through carbonaceous deposits on the door or seat.

2.4.7 The leveler door seat is bolted to the main door frame to facilitate its replacement in the event of damage to the sealing surface and is manufactured from NFCI to accommodate thermal stresses.

2.4.8 A one-piece leveler door heat shield which is also manufactured from NFCI is bolted to the inside surface of pusher side door frame opposite the leveler door.

2.5 SEAL

2.5.1 The picture frame type seals, as shown in Figure 2-10 for the USS-2 (Koppers) door and in Figure 2-11 for the USS-1 (Wilputte) door, were selected because of their flexibility and ease of manufacture. The seal is fabricated from four sections of MC10 x 6.5 NiCuTi steel channels welded with vertical joints at their corners to minimize fatigue stresses in the weld areas.

2.5.2 The seal is supported between the door frame and plug with the plug retainer bolts attached to the plug retainer plate.

2.5.3 A separate seal plate is supported by the same retainer bolts to shield both the seal and door from direct thermal radiation between the plug segments.

2.5.4 High-temperature gasketing is provided between the door and seal, the seal and seal plate, and the seal plate and plug retainers to ensure intimate contact of the seal with the door body and the plug segments, and also to reduce conductive heat transfer from the plug to the seal and main door frame.

2.5.5 The length of the unsupported portion of the seal is 4 inches (101.6 mm) to provide sufficient flexibility for accommodating door or jamb bowing and irregularities and waviness of the jamb sealing surface.

2.5.6 The design loading of the seal edge is 125 lb./in. (21.9 N/mm) and the operating loading is 100 lbs./in. (17.5 N/mm).

2.6 GUIDE/STOP BLOCKS

To ensure proper door placement on the ovens and to protect the seal from inadvertent damage by the latch hook, combination guide/stop blocks are provided on both sides of the door frame and at both upper and lower latch locations. The blocks are attached to the door frame with friction bolts as shown in Figures 2-1 and 2-5. The forward edges of all four guide/stop blocks extend an equal distance from the door frame and nominally 1/8 inch (3.2 mm) behind the main door seal edge and thus serve as door stops to prevent overstressing the door frame, control the seal deflection at the point of load application and to ensure that the door is properly inserted into the oven. Shims are provided between the door frame and the guide/stop blocks to accommodate variations in door and jamb widths to ensure that the 3/16- to 1/4-inch (4.7 to 6.3 mm) clearance between the hooks and the blocks is maintained.

2.7 PLUGS

2.7.1 The door plug for the USS-2 door is a multiple-segment, alumina-silica castable, and the door plug for the USS-1 door is a multiple-segment, silica brick. Both types are discussed in more detail in Section 9 of this manual.

2.7.2 The plug retainers for the USS-2 doors are fabricated from either 1/2" or 3/4" (12.7 mm or 19 mm) steel plates with "V" type anchors of 5/16 inch (7.9 mm) diameter, wax-coated stainless-steel rods welded to the retainer plates in staggered fashion. The plug retainers for the USS-1 doors are fabricated from special steel channels welded into a rectangular frame.

2.7.3 Each retainer plate for the USS-2 doors is attached to the door frame with two top bolts and two (or four) bottom bolts. The retainer bolt holes for the bottom retainer bolts are slotted to allow for differential thermal expansion between the plug and the door frame. Each retainer frame for the USS-1 doors is attached to the door frame with two top bolts and two (or four) bottom bolts, and mating clips which permit the door plug and seal to expand independent of the door frame.

2.7.4 For the USS-2 doors, caulking rings are provided in countersunk holes in the door frame beneath the retainer nuts to prevent gas leakage through the bolt holes in the door frame.

2.7.5 There are four plug segments on the pusher-side door and five plug segments on the coke-side door.

2.7.6 A clearance of 1-1/4 inches (31.7 mm) is provided between the bottom surface of the bottom plug retainer and the oven floor for both pusher and coke-side doors. A 3/4-inch (19 mm) clearance is provided between the sides of the plugs and the oven walls for both pusher and coke side doors.

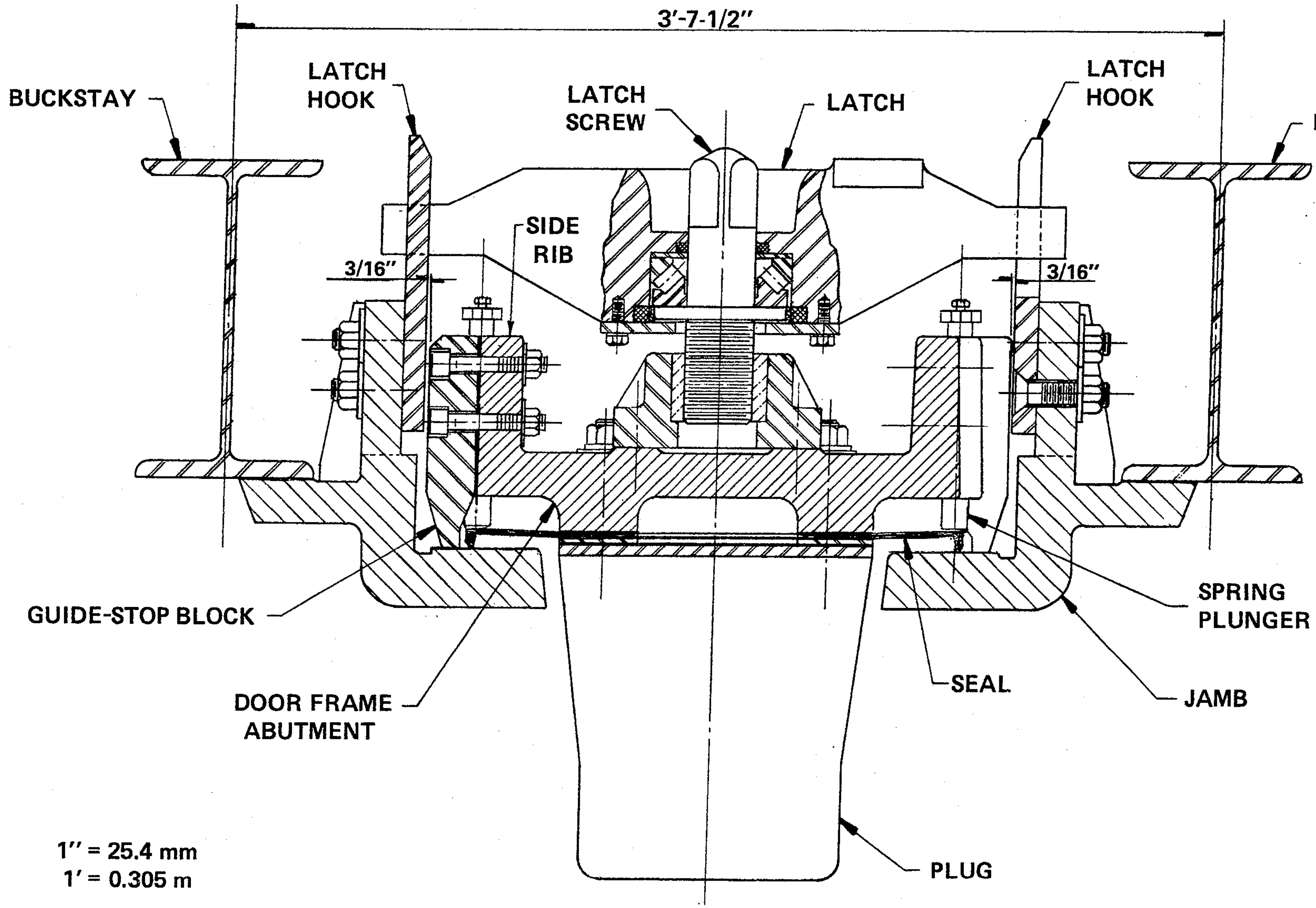
2.8 JAMBS

2.8.1 For the USS-2 door, the door jamb cross section is similar to that for a conventional Koppers battery as shown in Figure 2-1 and is manufactured from NFCI. For the USS-1 door, the door-jamb cross section is similar to that for a conventional Wilputte battery, as shown in Figure 2-5, and is manufactured from grey cast iron (A319T). For new jambs, the material should be NFCI.

2.8.2 For the USS-2 door, the door support consists of two opposing steel bars bolted to the inside surfaces of the jamb stems and shown in Figure 2-3. For the USS-1 door, the door is supported on a solid steel block welded to the bottom of the door frame as shown in Figure 2-6.

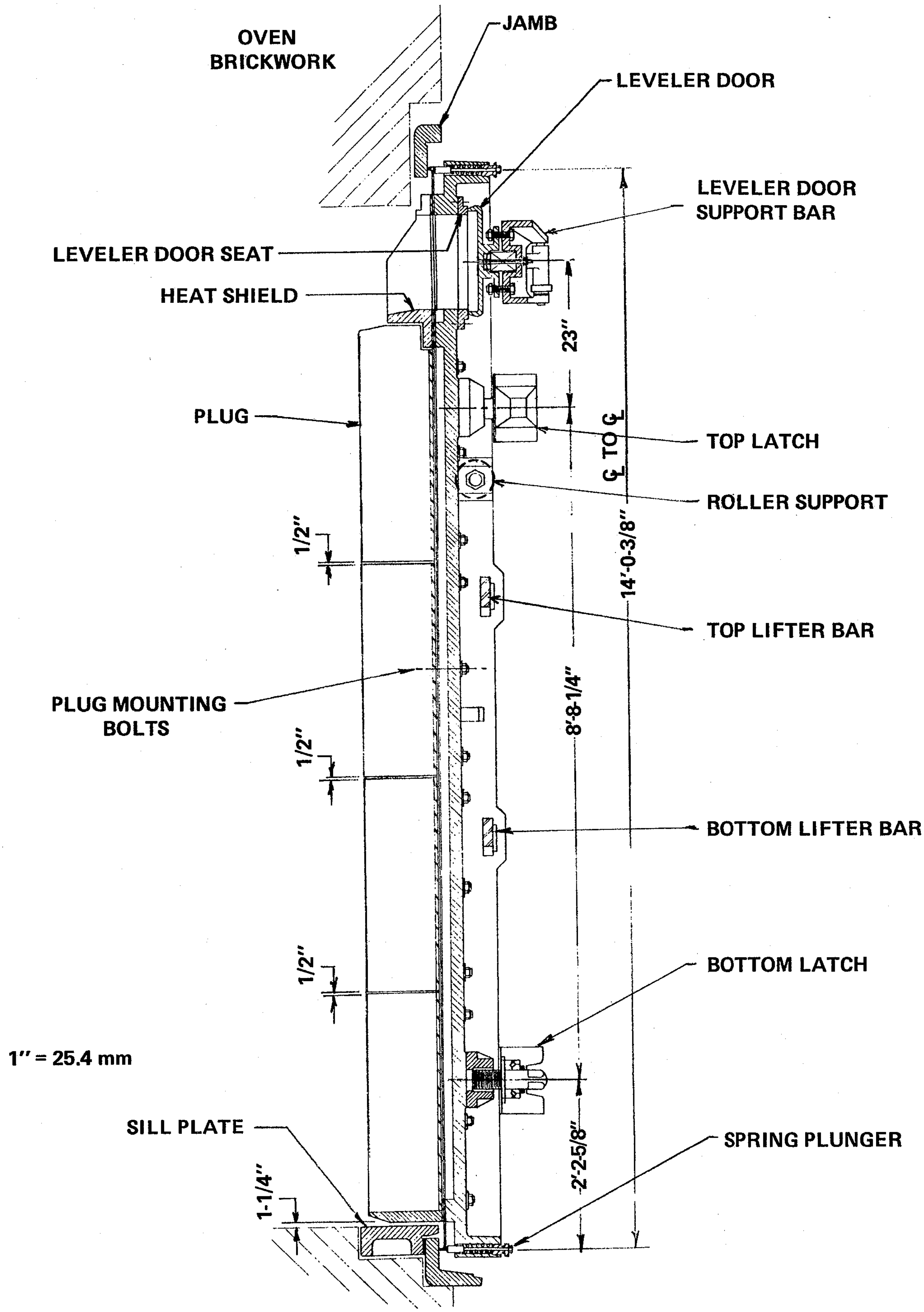
2.8.3 For both types of doors, the surface finish of the seal surface is a minimum of 125 RMS.

2.8.4 Jamb camber over its entire length when manufactured should not exceed 1/8-inch, but the camber of the sealing surface after installation should not exceed 1/32 inch.



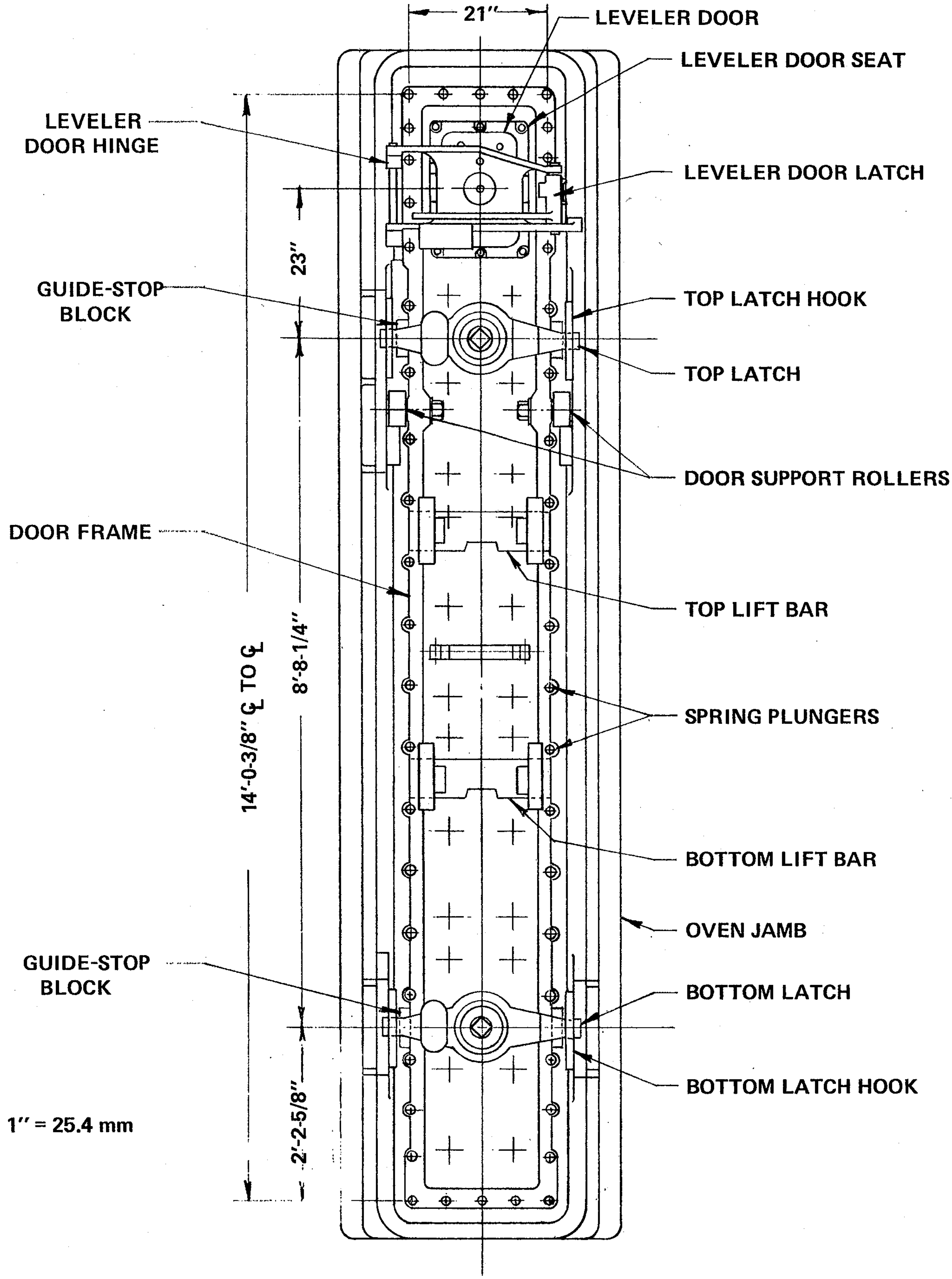
GENERAL ARRANGEMENT OF USS-2 COKE-OVEN DOOR, GENEVA WORKS

Figure 2-1



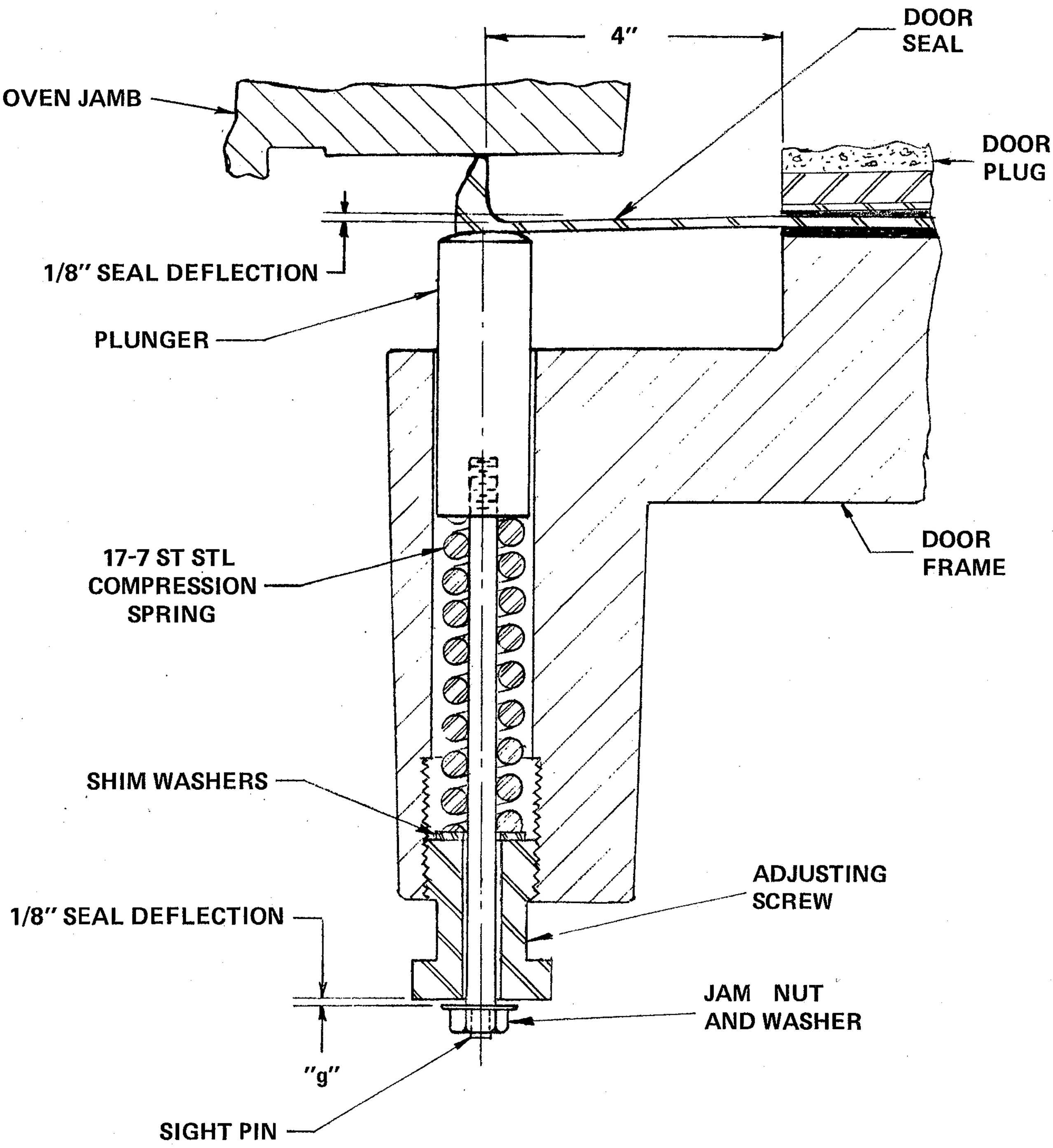
GENERAL ARRANGEMENT OF USS-2 COKE-OVEN DOOR, GENEVA WORKS

Figure 2-2



GENERAL ARRANGEMENT OF USS-2 COKE-OVEN DOOR, GENEVA WORKS

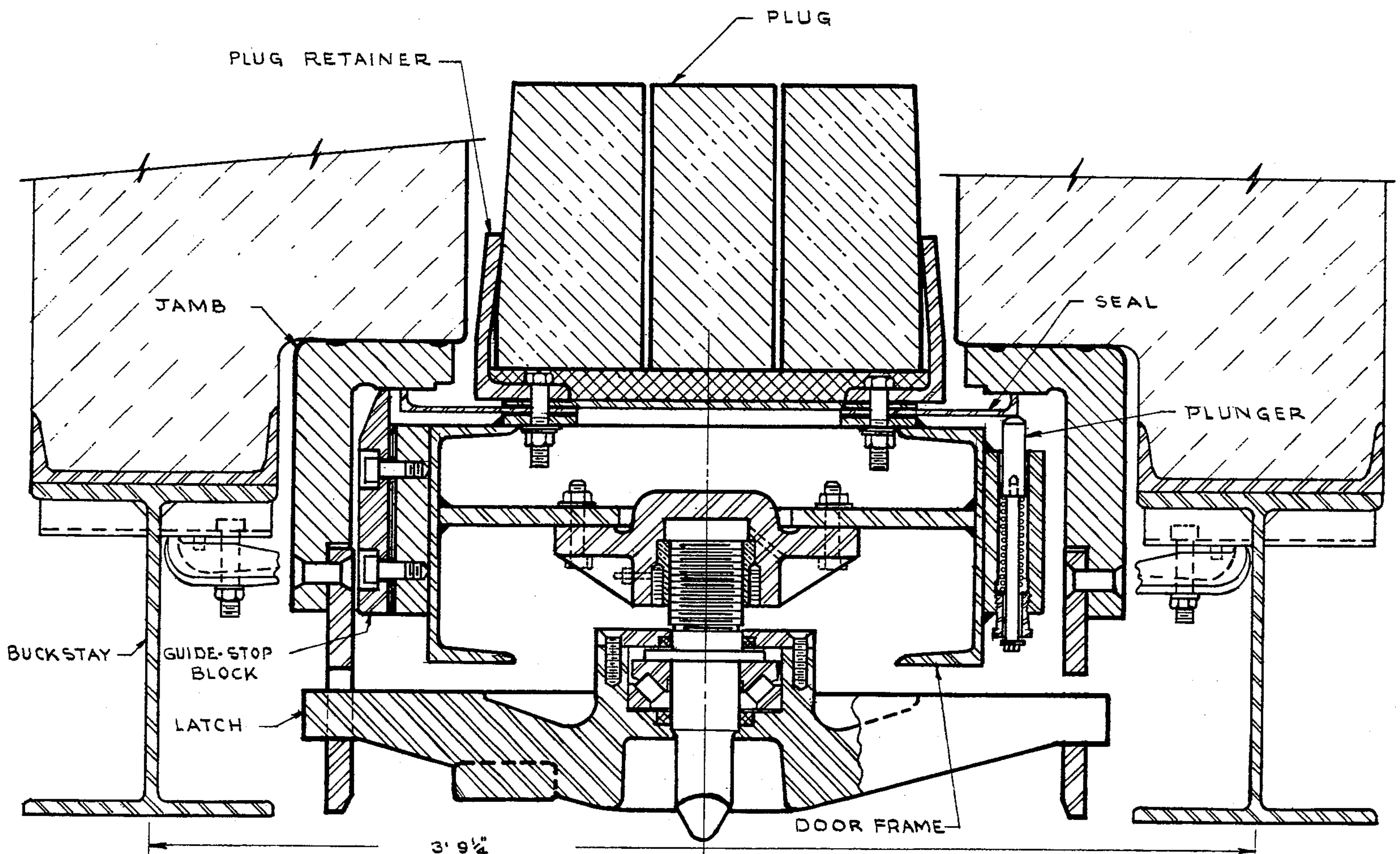
Figure 2-3



1" = 25.4 mm

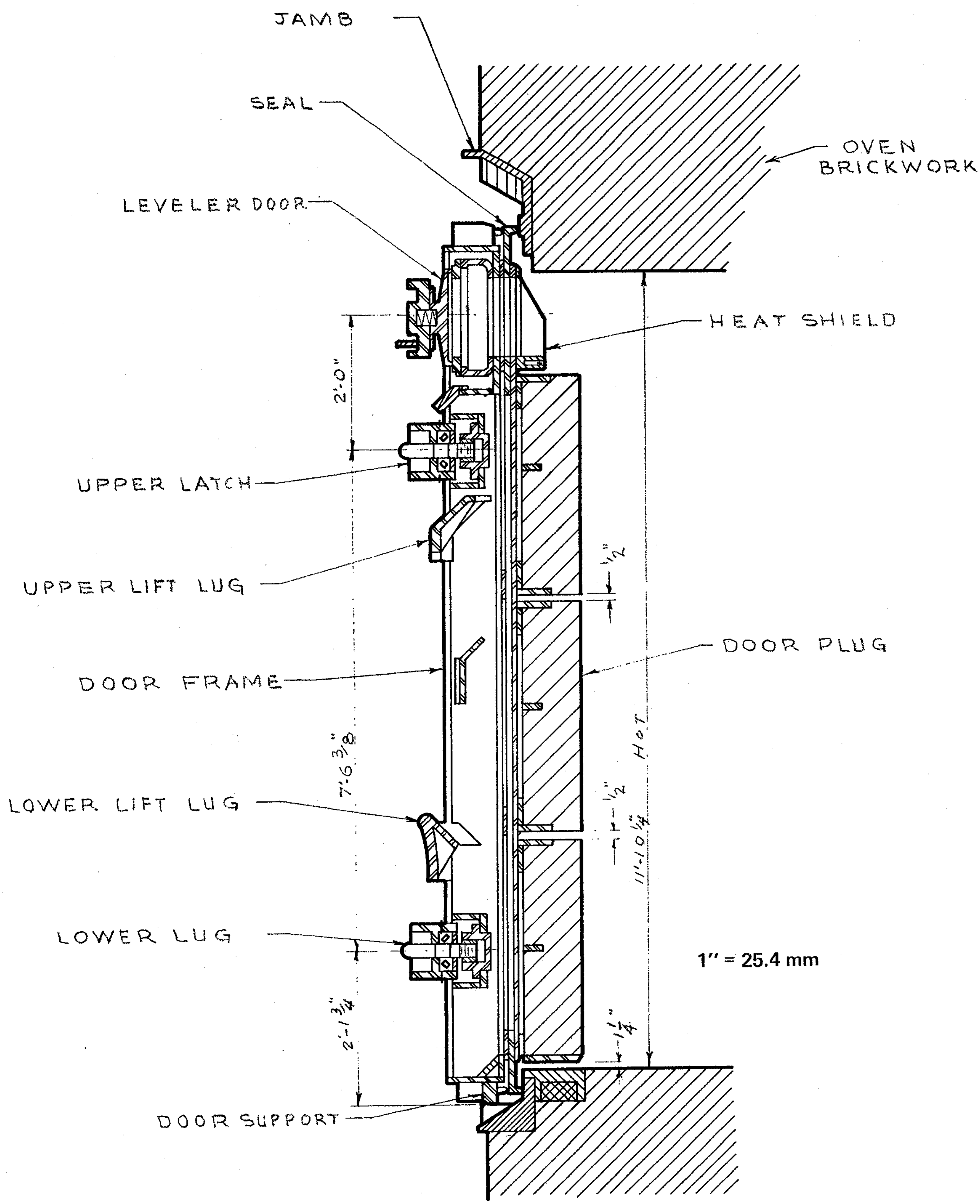
USS-2 PLUNGER ASSEMBLY INSTALLED IN DOOR FRAME WITH DOOR LATCHED TO OVEN AND SEAL DEFLECTED 1/8" AWAY FROM JAMB - GENEVA WORKS

Figure 2-4



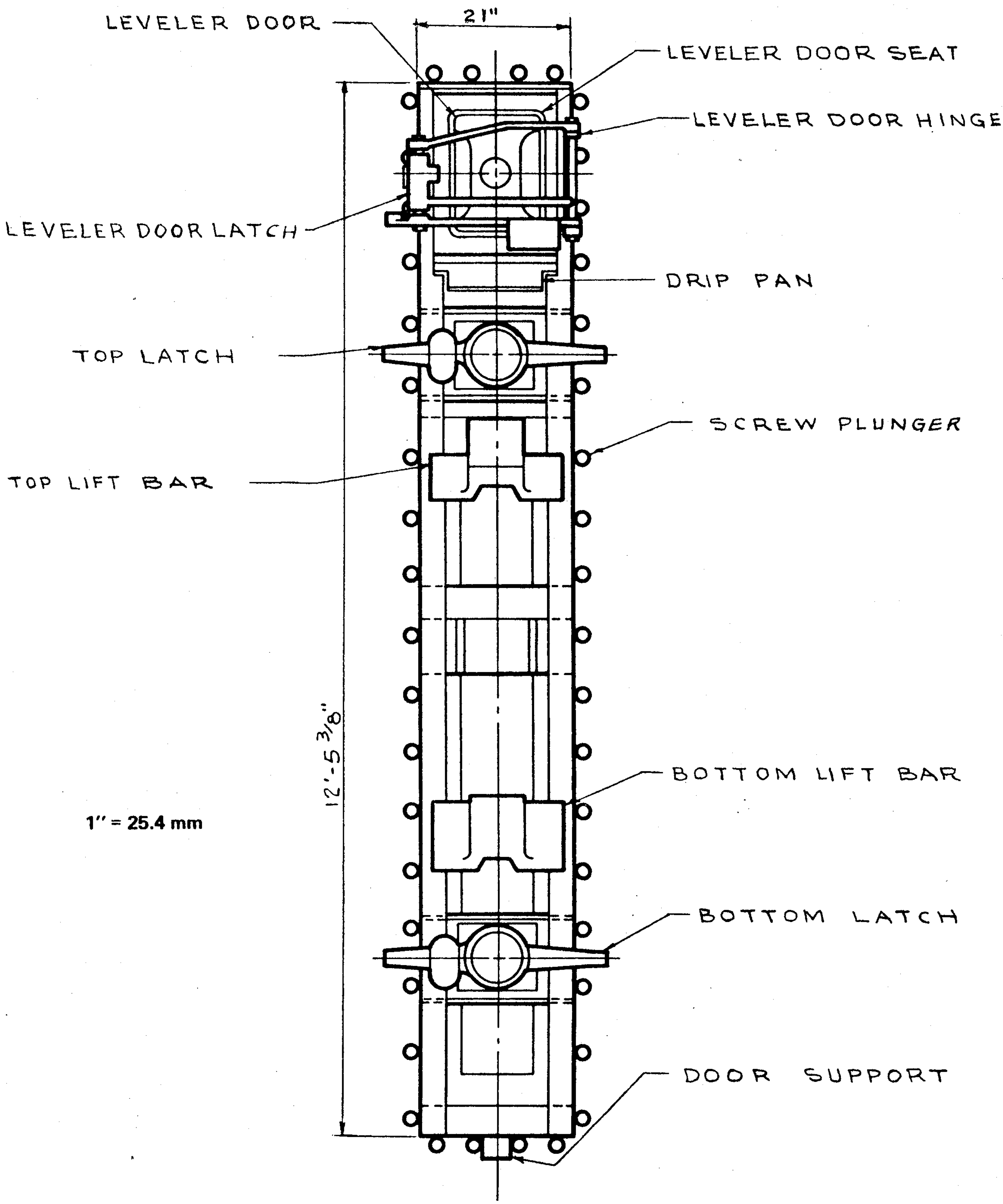
CROSS SECTION AT LATCH OF USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 2-5



ELEVATION SECTION OF USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

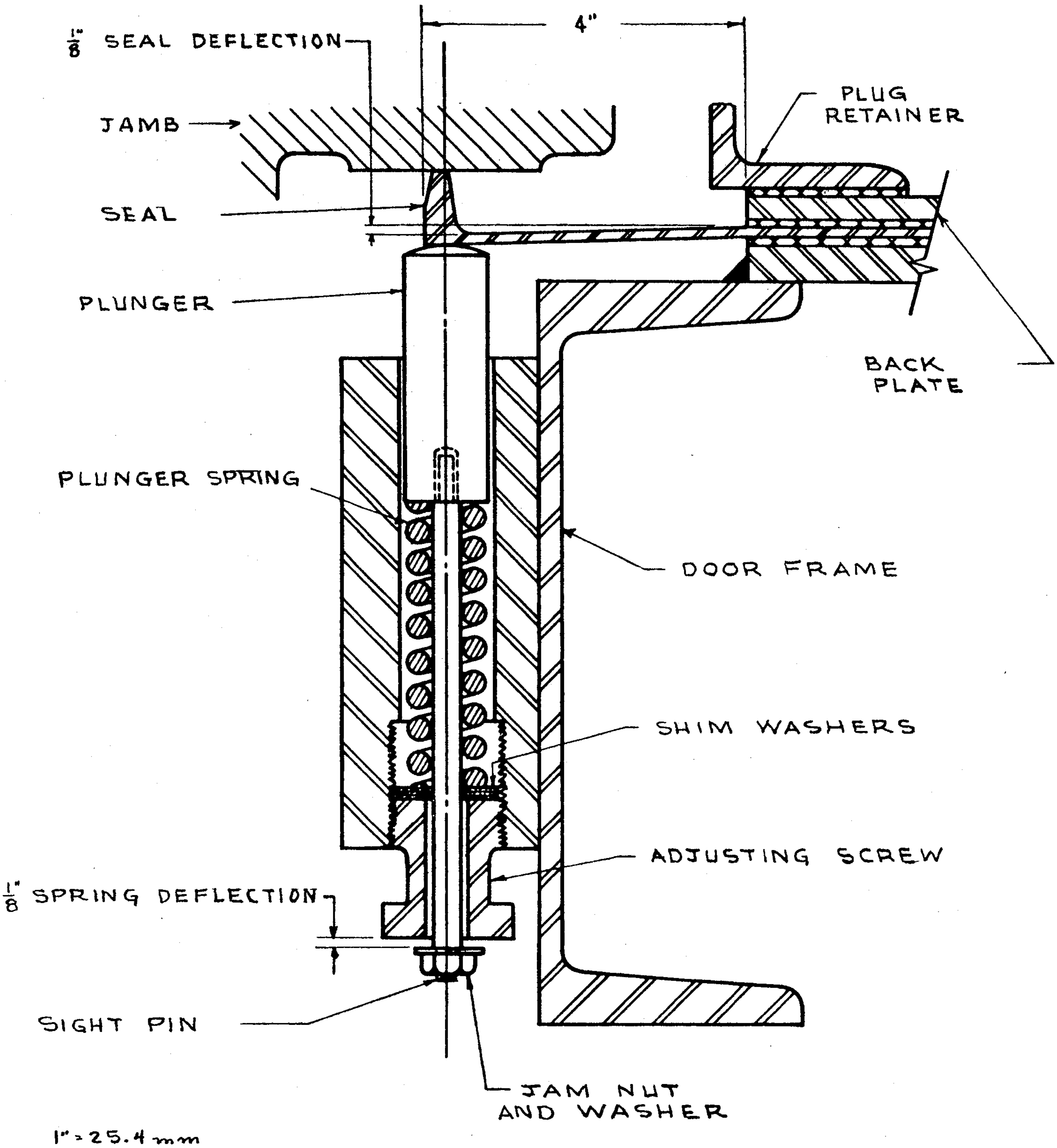
Figure 2-6



1" = 25.4 mm

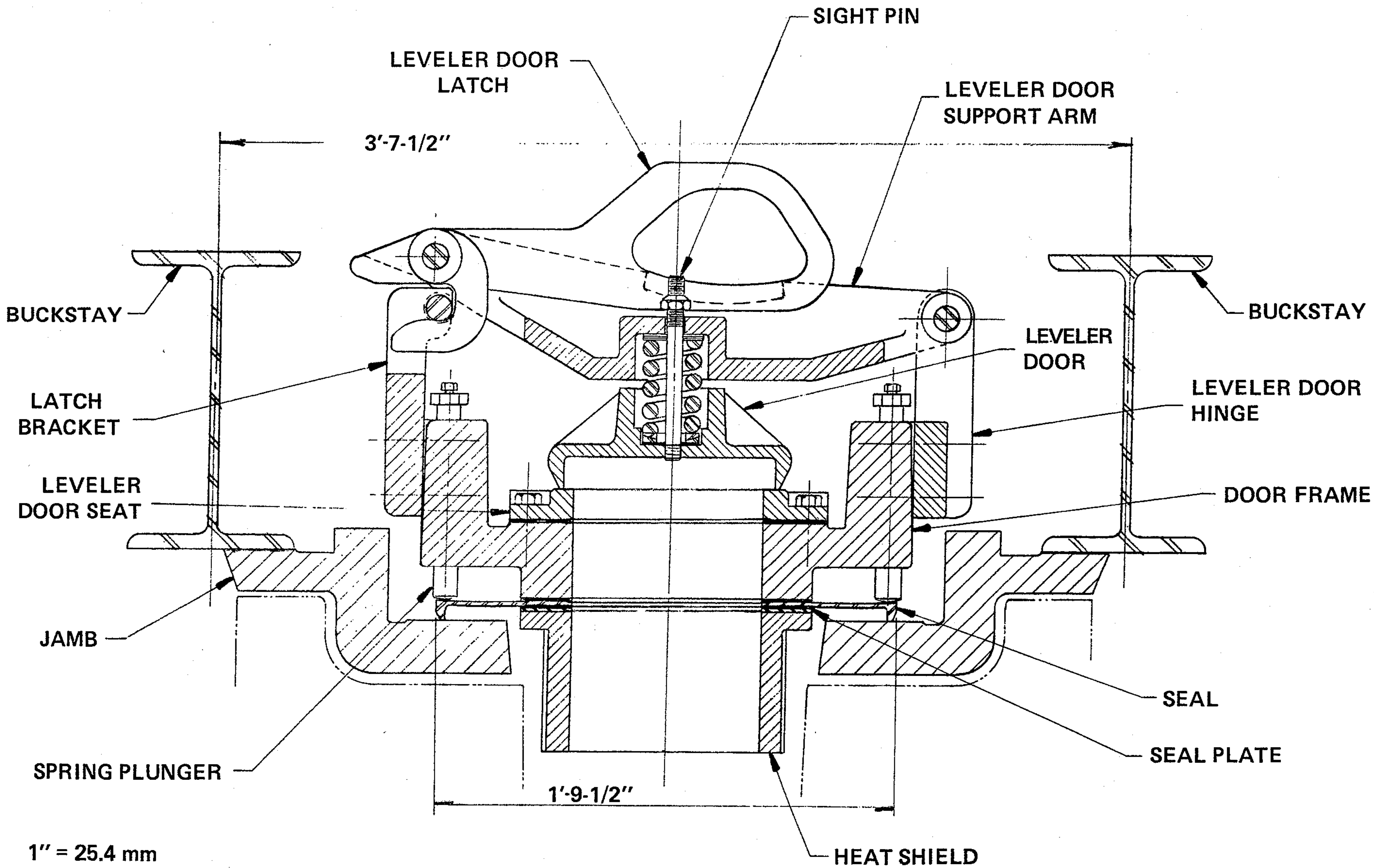
ELEVATION FRONT VIEW OF USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 2-7



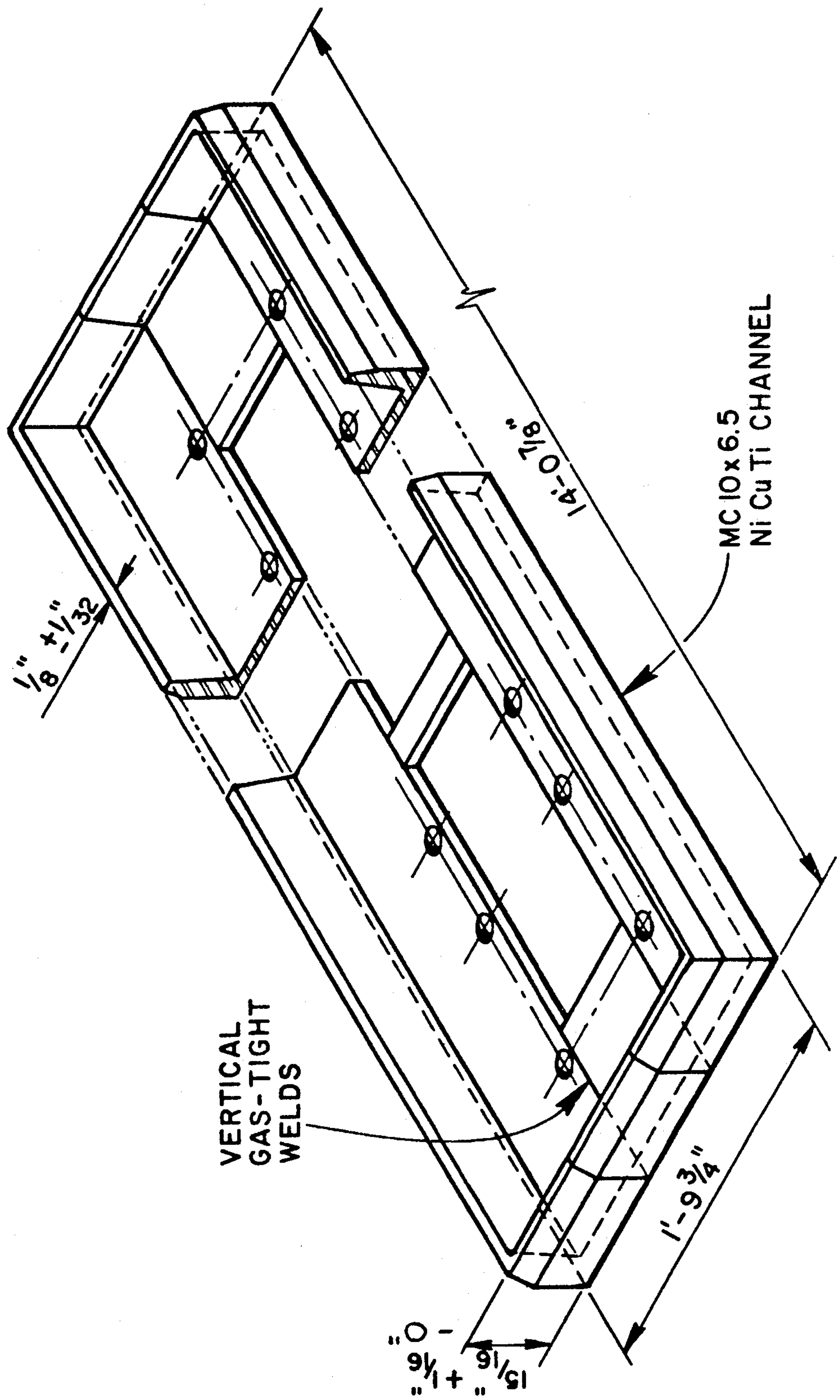
SPRING-PLUNGER ASSEMBLY FOR USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 2-8



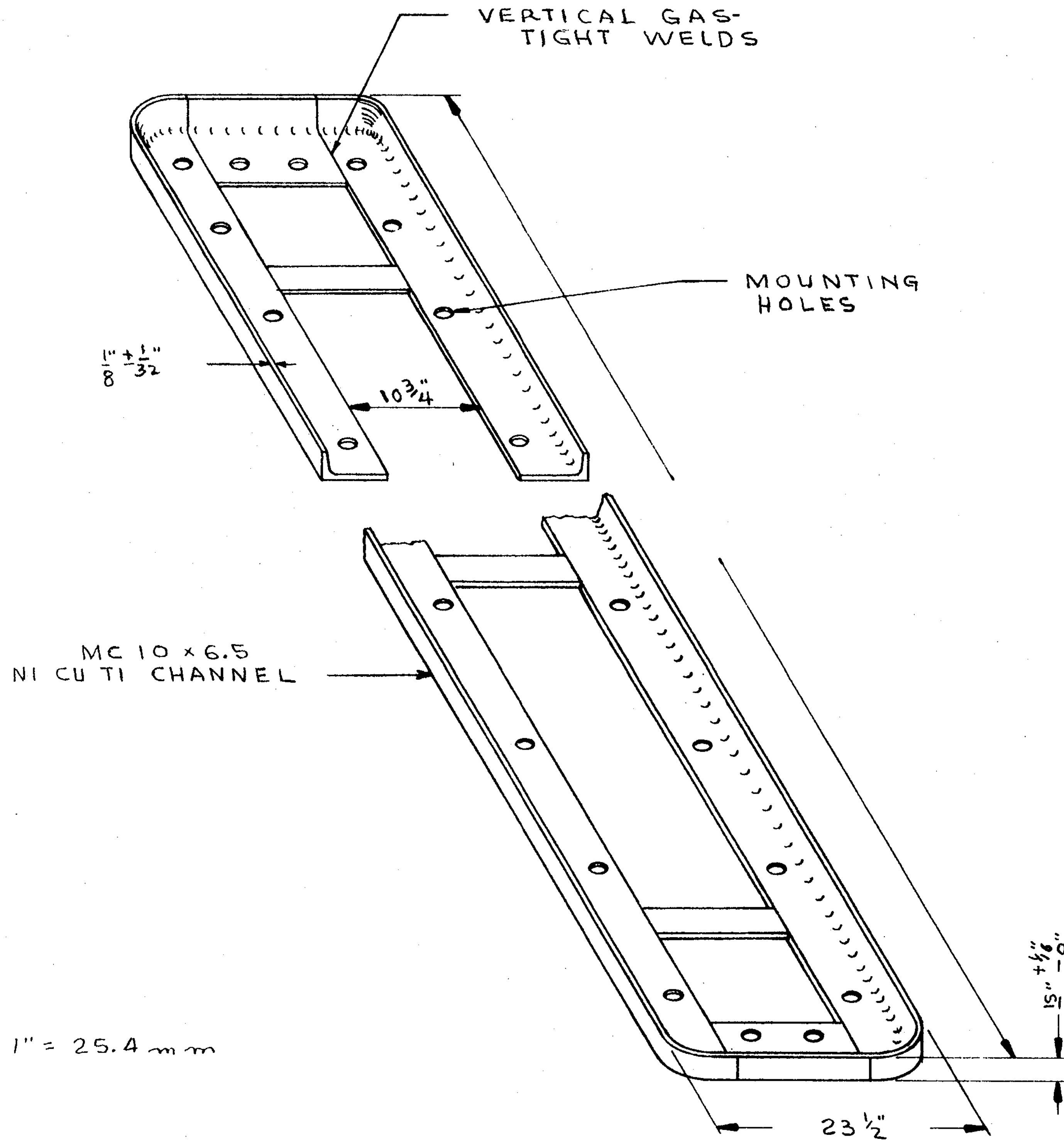
GENERAL ARRANGEMENT OF LEVELER DOOR FOR USS-2 COKE-OVEN DOOR, GENEVA WORKS

Figure 2-9



TITLE PICTURE FRAME SEAL FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS, COKE SIDE

Figure 2-10



PICTURE FRAME SEAL FOR USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3, COKE SIDE

3. INSPECTION AND ASSEMBLY

For optimum performance of the door system, it is important that all door components (without exception) be manufactured to design specifications and that each door component be assembled in the proper manner. The following inspection and assembly guidelines should be adhered to.

3.1 DOOR FRAME

3.1.1 The oven-door-frame surfaces to which any components are to be attached should be free of flaws, tar, carbon deposits, or other foreign matter.

3.1.2 The door frame should be inspected for cracks, and all cracks should be repaired in accordance with the American Welding Society Specification A5.15-69, "Welding Rods and Covered Electrodes for Welding Cast Iron."

3.1.3 The finished door-seal-seat surface waviness should not exceed a variation of 0.125 inch (3.17 mm) over its entire length. This can be checked by stretching a wire or cord between the ends of the door frame and using the roller gage, as shown in Figure 3-1.

3.1.4 The variation in door-seal-seat surface flatness should not exceed 0.005 inch (0.127 mm) in 12 inches (0.3 m) and can be checked with 12-inch (0.3 m) metal straightedge and feeler gages, as shown in Figure 3-2.

3.1.5 Door twist on the door-seal-seat surface should not exceed 1/8 inch (3.2 mm), as shown in Figure 3-3.

3.1.6 All plunger holes should be thoroughly cleaned of tar, oxides, carbon deposits, or other foreign matter. The plunger holes should meet the hole dimensions shown in Figure 3-4. The threaded portion of the holes are particularly critical and should be retapped if necessary to ensure the plunger screws turn freely by hand. The drilled portion and the threaded portion of the plunger holes should be lubricated with NEVER SEEZ grease or an equivalent high temperature grease.

3.1.7 The mounting holes for the door support roller should be free of machining burrs and aligned perpendicular to the roller and nut seat surfaces as shown in Figure 3-5.

3.1.8 Threaded holes for all appendages should be free of all foreign matter and lubricated with NEVER SEEZ or equivalent high temperature grease.

3.2 SPRING PLUNGERS

3.2.1 The plungers and sight pin should be free of tar, oxides, carbon deposits, burrs, and other foreign matter, and inspected to ensure that they are the proper dimensions. A gage to check the plunger and sight pin dimensions is shown in Figure 3-6. All surfaces of the plungers and sight pins should be lubricated with NEVER SEEZ or an equivalent high temperature grease.

3.2.2 Plunger screws should be thoroughly cleaned and inspected for damaged threads, and repaired or replaced as required. A gage to check the screw-length and center-hole dimensions is shown in Figure 3-7. The plunger-screw threads should be lubricated with NEVER SEEZ grease or an equivalent high temperature grease.

3.2.3 Plunger springs should be checked to ensure that they meet the specifications shown in Figure 3-8. The outside diameter and the free height of these springs can be checked with the spring gage shown in Figure 3-9. Each spring should be load-tested with a suitable spring tester to the 1100 ±90 pound (4893 ±400 N) capacity at the 1/2-inch (12.7 mm) deflection from free height. Spring-testing units can be purchased commercially. All spring ends must be ground and squared and all sharp edges should be removed.

3.3 LATCH COMPONENTS

3.3.1 Latches, bearings, bushings, support blocks, and screws should be thoroughly cleaned of all tar, oxides, carbon deposits, or other foreign matter and be inspected for damage and replaced or repaired as required.

3.3.2 Latch bore dimensions should be checked against Figure 3-10. Latch bores which are less than that shown in Figure 3-10 must be rebored to proper size to avoid excessive bearing-fit stresses. Latch bores that are oversize must be replaced or be built up and rebored to the sizes shown in Figure 3-10. Solid bearings should not be used even as temporary replacements. Similar inspection and repair procedures apply to the latch dimensions for the grease seals, latch screws, and latch bushings.

3.3.3 Grease holes, vent holes, and grease grooves in the latch and in the latch bracket and bushing (Figure 3-11) should be free of any foreign matter.

3.3.4 Latch screws, bushings, and bearings should be lubricated with high-temperature grease meeting Requirement No. 355 High Temperature EP GREASE No. 2 HLGI Grade (265-295 penetrant) as identified in U. S. Steel Lubrication Engineers Manual.

3.4 LEVELER DOORS

3.4.1 The leveler door supporting hinge brackets, latches, pins, screws, and nuts should be free of tar, oxides, carbon deposits, or other foreign matter and inspected for cracks, burrs, and other flaws. These components should be repaired or replaced as required.

3.4.2 The welding repairs on any portion of the leveler door components that are made from cast iron should be made in accordance with the welding procedures outlined previously in Section 3.1.2.

3.4.3 The leveler-door-seat surface roughness should not exceed 63 RMS. Surface-finish blocks, which are commercially available, should be used for reference comparisons.

3.4.4 The leveler-door-seat and the leveler-door knife-edge surface should not exceed a total variation in waviness or flatness of 0.001 inch in 12 inches (0.025 mm in 0.3 m). This can be checked with a metal straight edge and feeler gage as shown in Figure 3-12.

3.4.5 The leveler-door knife-edge surface roughness should not exceed 63 RMS and preferably 32 RMS. Surface-finish blocks, which are commercially available, should be used for reference comparisons.

3.4.6 All surfaces of the leveler-door knife edge and seat must lie in the same plane. This can be checked with a metal square in the manner shown in Figure 3-13.

3.4.7 The leveler doors and leveler-door-seat surfaces that are not within tolerance should be remachined.

3.4.8 The leveler-door knife-edge width must not exceed 1/8 $\pm$1/32 inch (3.17 $\pm$0.79 mm), as shown in Figure 3-14. Leveler doors with sealing-edge widths exceeding 5/32-inch (3.96 mm) can be hand-ground on the outside surface, but care must be taken not to exceed the 3/32-inch (2.38 mm) minimum width. Leveler doors with sealing-edge widths less than 3/32 inch (2.38 mm) should not be used.

3.4.9 All sharp corners, burrs, and razor edges on the leveler-door knife edge should be removed with fine emery cloth or a hand stone.

3.4.10 The leveler-door springs, shims, spherical washers and sight pins must be thoroughly cleaned of tar, carbon deposits, or other foreign matter. The springs must meet the specifications shown in Figure 3-15. The outside diameter and free height of the leveler-door springs should be checked with the spring gage shown in Figure 3-16. Each spring should be load-tested with a suitable spring tester to ensure the 2700 $\pm$200 pounds (12.0 $\pm$0.9 kN) capacity at 4-1/4 ±1/16-inch (107.9 ±1.58 mm) height. Spring-testing units can be purchased commercially. All spring ends must be ground and squared and all sharp edges should be removed.

3.4.11 Leveler-door hinge components should be lubricated with AMOCO-INDOIL No. 15 or an equivalent.

3.5 SEAL

All seals should be carefully inspected for the following:

3.5.1 The surface roughness of the knife edge of the seal should not exceed 125 RMS (preferably 63 RMS), as shown in Figure 3-17. Commercially available surface-finish blocks should be used for reference comparisons.

3.5.2 Nicks, gouges, file marks, or other surface flaws on the knife edge are not permitted. All sharp corners, burrs, and razor edges on the knife edge should be removed with fine emery cloth or hand stones.

3.5.3 Corner welds should be inspected to ensure that they are gas-tight and free of all weld spatters.

3.5.4 The entire perimeter of the knife-edge width of the seal should be 1/8 ±1/32 inch (3.17 ±0.8 mm), as shown in Figure 3-17. Seals with knife-edge widths less than 3/32 inch (2.38 mm) should not be used. Seals with knife-edge widths greater than 5/32 inch (3.96 mm) can be hand-ground on the outside surface (Figure 3-17) with portable hand grinders, but care must be taken not to exceed the minimum thickness of 3/32 inch (2.38 mm). Figure 3-18 shows a gage that can be used to check the knife-edge width.

3.5.5 The height of the seal knife-edge of the seal should be 15/16 inch to 1 inch (23.8 to 25.4 mm) and can be checked with the height gage shown in Figure 3-19.

3.6 GUIDE/STOP BLOCKS

3.6.1 Each guide/stop block should be inspected to ensure that the forward edge is at the proper distance from the mounting holes and the mounting-hole spacing is correct as shown in Figure 3-20-a for USS-2 doors and Figure 3-20-b for USS-1 doors. The location of the mounting holes in the door frame is also shown and should be checked. The ultimate dimension G = 7/8 inch (for USS-2 doors) or G = 1-3/16 inch (for USS-1 doors) is important to proper door functioning and will be covered in more detail below.

3.6.2 The forward surface of the block must be machined at 90° to the mounting surface as shown in Figures 3-20-a and 3-20-b, and be free of burrs and/or razor edges.

3.7 DOOR ASSEMBLY GUIDELINES

3.7.1 The leveler-door seat is assembled to the top of the pusher-side door over a 1/8 inch (3.2 mm) thick continuous, Fiberfrax gasket and torqued in the manner shown in Figure 3-21-a for USS-2 doors and Figure 3-21-b for USS-1 doors. This procedure will ensure that the seat does not lose its flatness during installation or in service. It is suggested that bolt torques be rechecked after 24 hours to ensure the Fiberfrax gasket "set" has not reduced the seat tightness. This is accomplished by first loosening each bolt and retorquing it again following the procedure shown in Figures 3-21-a and 3-21-b.

3.7.2 The leveler door is first assembled as shown in Figure 3-22 by inserting the spherical washer set over the Fiberfrax gasket. Inspect the assembly to ensure the top spherical washer can rotate freely before inserting the spring and shim pack. The sight pin is then threaded into the door body and wrench tightened, and the door assembly mounted to the leveler door support with the preload bolts and nuts. The nuts are hand tightened until the door support, the spring components and the door body are just metal-to-metal (no spring load). The sight-pin nut is then installed on the sight pin and adjusted until it is flush with the back surface of the door support. This nut should not be moved from this position except for reservicing the doors.

3.7.3 The preload nuts are then tightened alternately until the gap E' between the door and door support is approximately 7/16 inch (11.1 mm). It is important that the dimension E' is equal on both sides of the door as shown in Figure 3-22.

3.7.4 Figure 3-23 shows the leveler door arrangement in plan-cross section with the leveler door preassembly properly mounted to the main door body and in the latched position. If properly assembled, the dimension E' is approximately equal to 3/8 inch (9.5 mm). The gap "N" (see Figure 3-22) between the preload nuts and the leveler door flanges should be approximately 1/16 inch (1.5 mm). The gap G between the sight-pin-retainer nut and the leveler door should be approximately 7/16 inch (11.1 mm) which when multiplied by the spring constant K of the leveler door spring gives the spring load on the leveler door. For the proper door assembly, the designed door load is $P = 7/16\ k = 2700$ pounds (11.9×10^3 N) for $k = 6178$ pounds per inch (1081 N/mm). The latch lever torque that is equivalent to the 2700 lbs. spring load is approximately 85-100 ft. lbs. (115.3-144 Nm) applied at the end of the lever arm as shown in Figure 3-23, and is also equivalent to Q = 71-84 lbs. (316-374 N) force on the latch lever. If either the spring deflection (or latch lever torque) value cannot be obtained with the original shim pack, or the leveler door does not contact the seat squarely when it is being closed, it may be necessary to disassemble the door to increase or decrease the height of the shim pack. The door should be reassembled in accordance with the steps 3.7.2 through 3.7.4 above. When the proper spring load on the door is obtained, shims should not be changed while in service to accommodate heat set of the springs. If spring heat set occurs, the springs should be replaced.

3.7.5 Care should be taken to ensure that the leveler door sealing knife edge will contact the seat squarely during the latching of the door to prevent damage to the door seal edge or seat. Improper spring preload or springs with ends that are not square will cause incorrect seating of the door, and will adversely effect sealing performance.

3.7.6 After obtaining the proper leveler-door load of 2700 lbs. when the door is latched, feeler gages should be used to ensure that gaps between the door and the seat do not exceed 0.002 inch (0.05 mm). Assemblies with gaps exceeding 0.002 inch should be disassembled and the leveler door and/or seat should be remachined or replaced.

3.7.7 Latch bearings should be assembled to the latch bars as shown in Figure 3-24. The outer race is placed in dry ice for approximately 45 minutes and the inner race is placed in a warm oil bath for approximately 30 minutes. The small grease seal and seal retainer ring are installed in the latch bar. The outer race is then placed into the latch bore until it is seated against the seal retainer ring. The inner race can then be slipped on the latch screw until it is seated against the screw shoulder. When the inner and outer races have attained room temperature, the latch screw (with the inner race) can be assembled to the latch bar as shown in Figure 3-24. The large grease seal and the screw retainer plate are then carefully assembled as shown. The latch assembly should now be checked for sufficient clearance "d" = approximately = 0.132 inch (3.3 mm) between the screw flange and the screw retainer plate to permit the ends of the latch to rotate 1/2 inch (12.7 mm) or approximately 2° relative to the screw. The latch bearings can now be lubricated with high-temperature grease (see section 3.3.4) via the grease fittings in the latch bar. This grease should also be applied to the latch screw and nut prior to mounting the latch to the door frame as shown in Figure 2-1.

3.7.8 With the door in the position shown in Figure 3-25, a 1/8-inch-(3.2 mm) thick* Fiberfrax gasket is placed on the door-seal-support pad. This gasket must be continuous over the entire pad surface, or may consist of several lengths with dovetail joints. Gaskets with flush joints should not be used.

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* Compressed thickness = 0.080 inch @ 8 psi.

3.7.9 The seal is then placed on the seal gasket so that all mounting holes are in alignment with the mounting holes in the door frame. If any of the seal holes are out of alignment with the door holes, the seal should be removed and the holes corrected. The seal must also be laterally and longitudinally centered on the door frame.

3.7.10 A second 1/8-inch-(3.2 mm) thick Fiberfrax gasket identical to the first gasket is placed on top of the seal.

3.7.11 The 1/4-inch-(6.4 mm) thick steel seal plate is placed on top of the second gasket taking care that the mounting holes are aligned with the mounting holes in the seal and door frame.

3.7.12 A third 1/8-inch-thick Fiberfrax gasket identical to the first two gaskets is then placed on the seal plate.

3.7.13 The leveler-door heat-shield casting is then mounted to the top of the pusher-side door frame as shown in Figure 3-26-a for USS-2 doors and Figure 3-26-b for USS-1 doors. Care should be taken to ensure the heat-shield casting is centered with the leveler-door opening in the door frame. The heat-shield bolt mounting torque should be about 50 ft.-lbs. (67.7 Nm) and the torque sequence is shown in Figure 3-27-a for USS-2 doors and Figure 3-27-b for USS-1 doors. Prior to door installation, the bolt torques should be rechecked to ensure the gasket "set" has not relieved the original torque.

3.7.14 The plugs can now be placed on the door frame making certain that the retainer bolts pass freely through the bolt holes in the seal plate, seal and the door frame. All plug segments and the seal must be laterally centered on the door frame and also properly positioned along the length of the door frame as shown in Figure 2-2. For USS-2 doors, the bottom surface of the bottom plug segment should be flush with the bottom surface of the seal pad and bottom surface of the seal plate as shown in Figure 3-28-a. For USS-1 doors, the bottom surface of the bottom plug segment should be 7 inches above the bottom surface of the door-support block as shown in Figure 3-28-b. For USS-2 doors, the top surface of the top plug segment on the pusher side door frame should be approximately 1/2 inch below the leveler door heat shield as shown in Figure 3-26-a. For USS-1 doors, the top surface of the top plug segment on the pusher-side door frame should be approximately 1/4 inch below the leveler-door heat shield as shown in Figure 3-26-b. There should be approximately 1/2 inch clearance between adjacent plug segments, which after bricking should be tamped with high-temperature ceramic fiber such as Kaowool.

3.7.15 High-temperature caulking rings are then installed over the plug retainer bolts and tamped carefully into the chamfered recesses in the door frame as shown in Figure 3-25.

3.7.16 The plug retainer bolt and nut threads should be lubricated with NEVER SEEZ or equivalent high-temperature lubricant. Plain washers, lock washers and nuts are then placed on the plug retainer bolts and the nuts adjusted until finger tight. The nuts are then torqued to the values and in the manner shown in Figure 3-29-a for USS-2 doors and Figure 3-29-b for USS-1 doors. It is important to note that the initial torques set at the factory may exceed these values, but are necessary to ensure the Fiberfrax gaskets will take an early "set." The relaxation or inherent "set" in such gasketing materials which usually occurs in the first 24 hours may relieve the initial torque values. Therefore, prior to door installation these torques should be checked by first loosening and then retightening the nuts to the torque values shown in the figure.

3.7.17 The seal knife edge should now be inspected for waviness which should not exceed a total variation of 0.125 inch (3.17 mm) over the entire length. This can be checked by stretching a wire or cord between the ends of the seal and using any suitable means (such as the roller gage shown in Figure 3-30) to measure the distance between the wire (or string) and the seal edge. Out-of-tolerance waviness should be corrected by using a suitable bending bar such as the one shown in Figure 3-31, with care so as not to damage the knife edge of the seal.

3.7.18 The seal knife edge should then be inspected between the plungers for flatness, which should not exceed a total variation of 0.004 inch per foot (0.10 mm per 304.8 mm) around the entire perimeter of the seal. This can be checked with a 12-inch (0.3 m) metal straightedge and feeler gage as shown in Figure 3-32. An alternative method for checking seal knife-edge flatness is by use of the dial gage shown in Figure 3-33. Out-of-flatness tolerance must be corrected, taking care not to damage the knife-edge surface. Suitable bending bars such as that shown in Figure 3-31 can be used for this purpose.

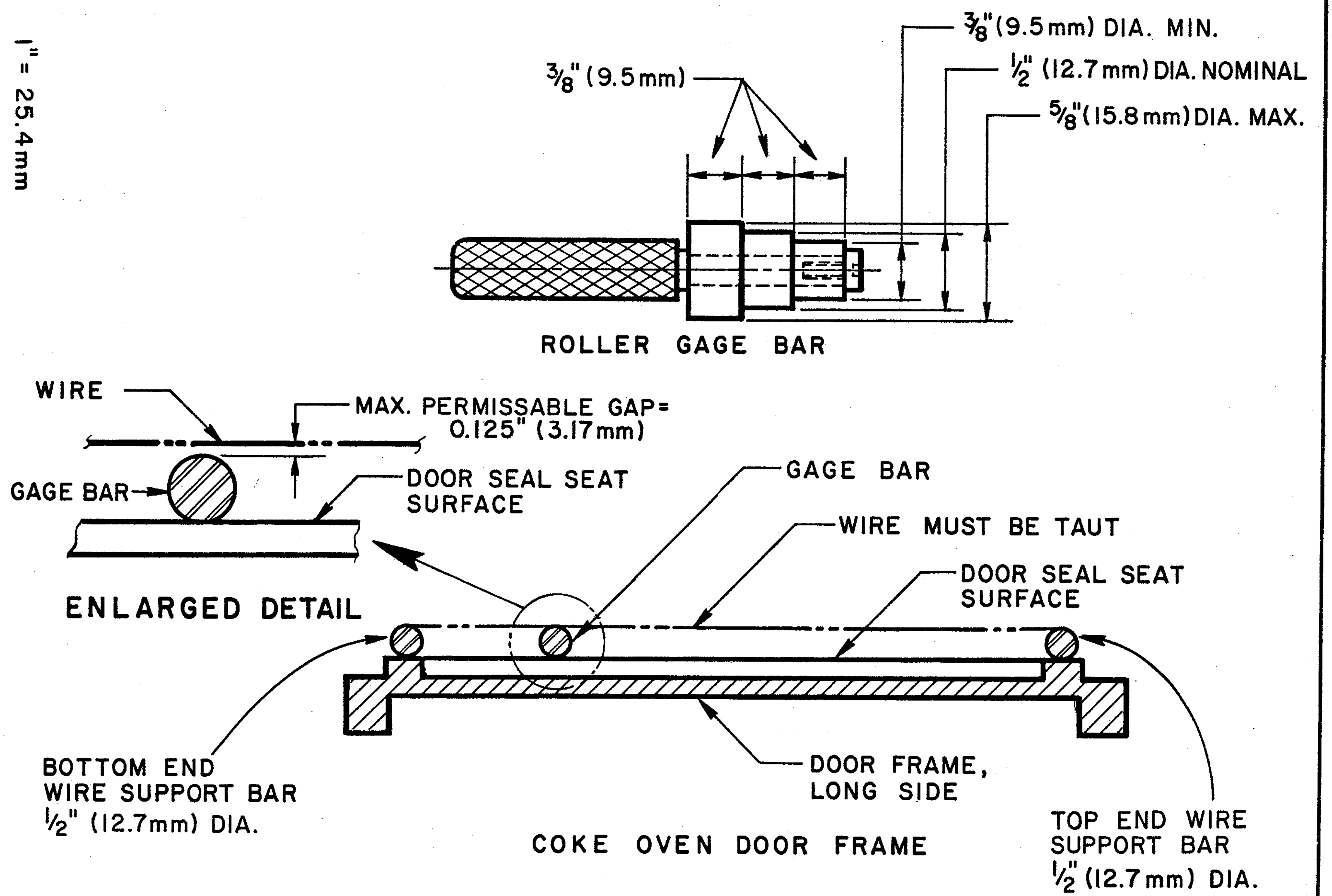
3.7.19 Each of the four corners of the seal knife-edge must lie in the same plane and can be checked with a metal square in the manner illustrated in Figure 3-34.

3.7.20 After the waviness and flatness tolerance of the seal have been established, the four guide/stop blocks can be assembled to the door frame in the manner shown in Figure 3-25-a for USS-2 doors and Figure 3-25-b for USS-1 doors. The cap-bolt threads should be lubricated with NEVER SEEZ or equivalent high-temperature grease. Shim stock provided with these blocks is used to obtain the 3/16-inch (+1/16 inch, -0 inch) side clearance between the blocks and the latch hooks of the particular oven on which the door will be used. It is important that the guide/stop blocks are seated tightly against all shim stock and that an equal number of shims are used on each side of the door frame. It is also important that the forward edges of all four blocks be the same distance (G = 7/8 inch for USS-2 doors and G = 1-3/16 inch for USS-1 doors) from the seal support pad of the door frame, and nominally 1/8 (+1/16 inch, -0 inch) behind the seal edge. The cap bolt nuts should be torqued to 80-90 ft.-lbs. (108.5-122.0 Nm) for USS-2 doors and 100 ft.-lbs. (135.5 Nm) for USS-1 doors. A guide gage such as that shown in Figure 3-36 can be used to check the distance between the opposing guide/stop blocks.

3.7.21 Prior to assembly of the spring plunger modules to the door frame, the shim stock provided should be used to ensure the sight pin washer and shoulder are flush with the face of the adjusting screw as shown in Figure 3-37. The adjusting screw threads and those in the door frame should be lubricated with NEVER SEEZ or equivalent high-temperature grease. The modules are then inserted into the door frame until the plungers just make contact with or are almost touching the back surface of the seal (no spring load). All plunger screws should turn easily by hand into the door frame.

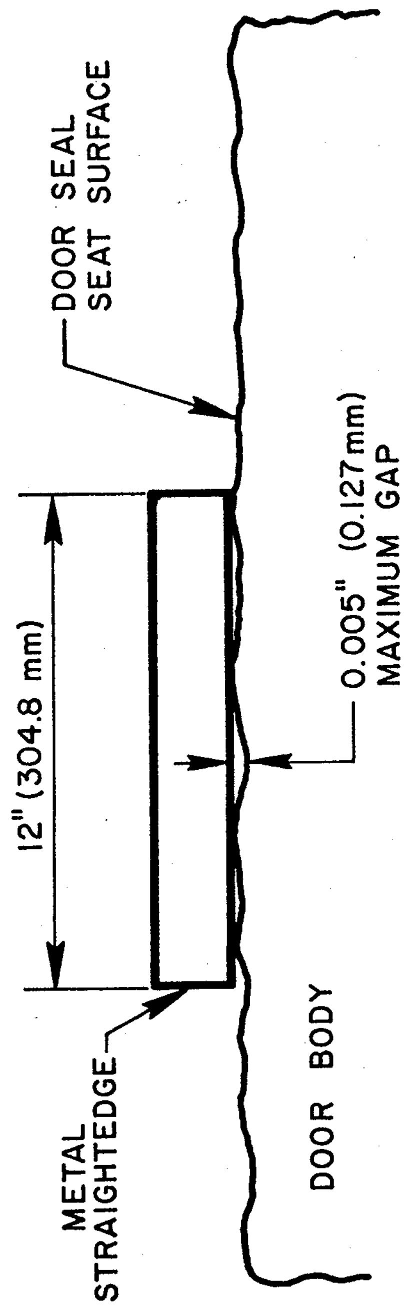
3.7.22 The assembly of the latch hooks and the door support plates to the jambs are by friction bolting. The ASTM A-325 1-inch bolts should be torqued from 47,250 lbs. minimum to 60,000 lbs. maximum tension in accordance with AISC Specifications for structural joints.

1" = 25.4mm



TITLE: METHOD FOR MEASURING WAVINESS OF COKE OVEN DOOR FRAME

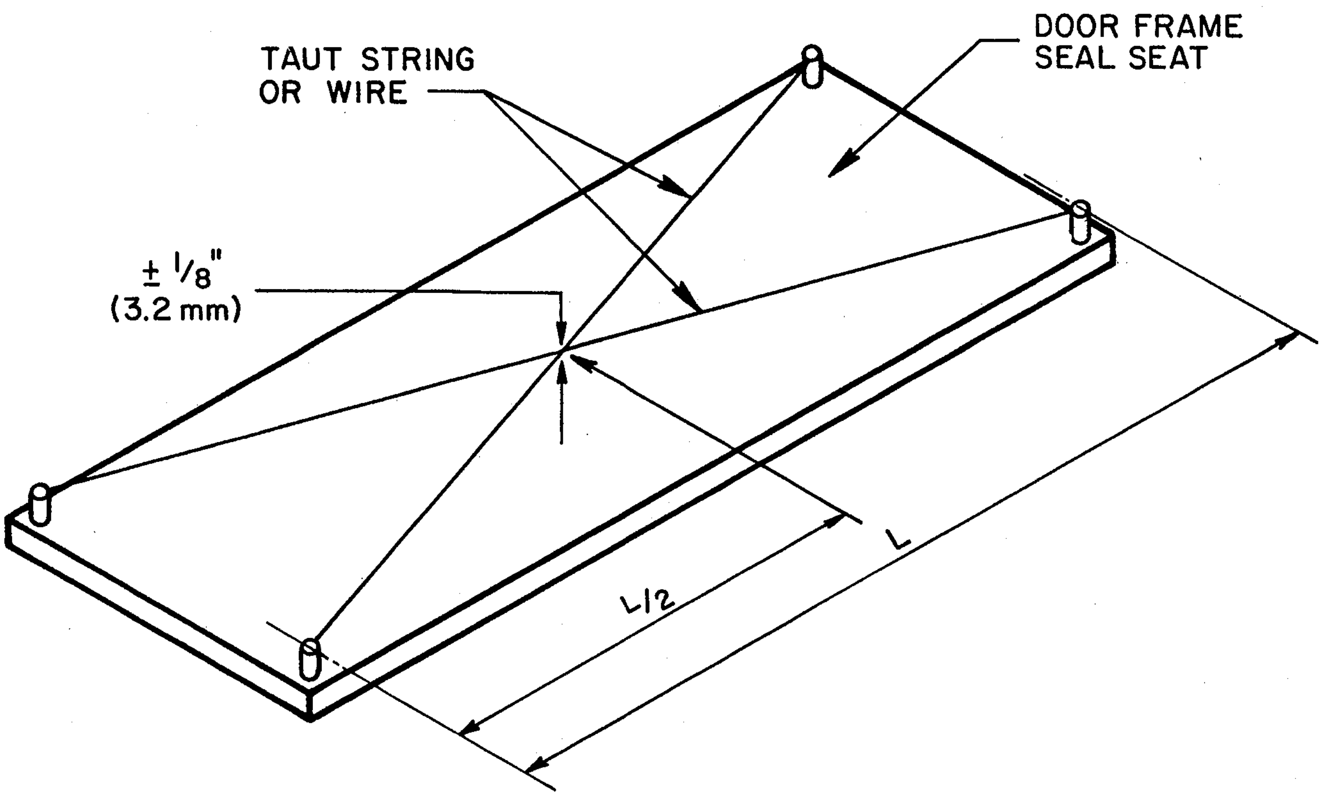
Figure 3-1



1" = 25.4 mm

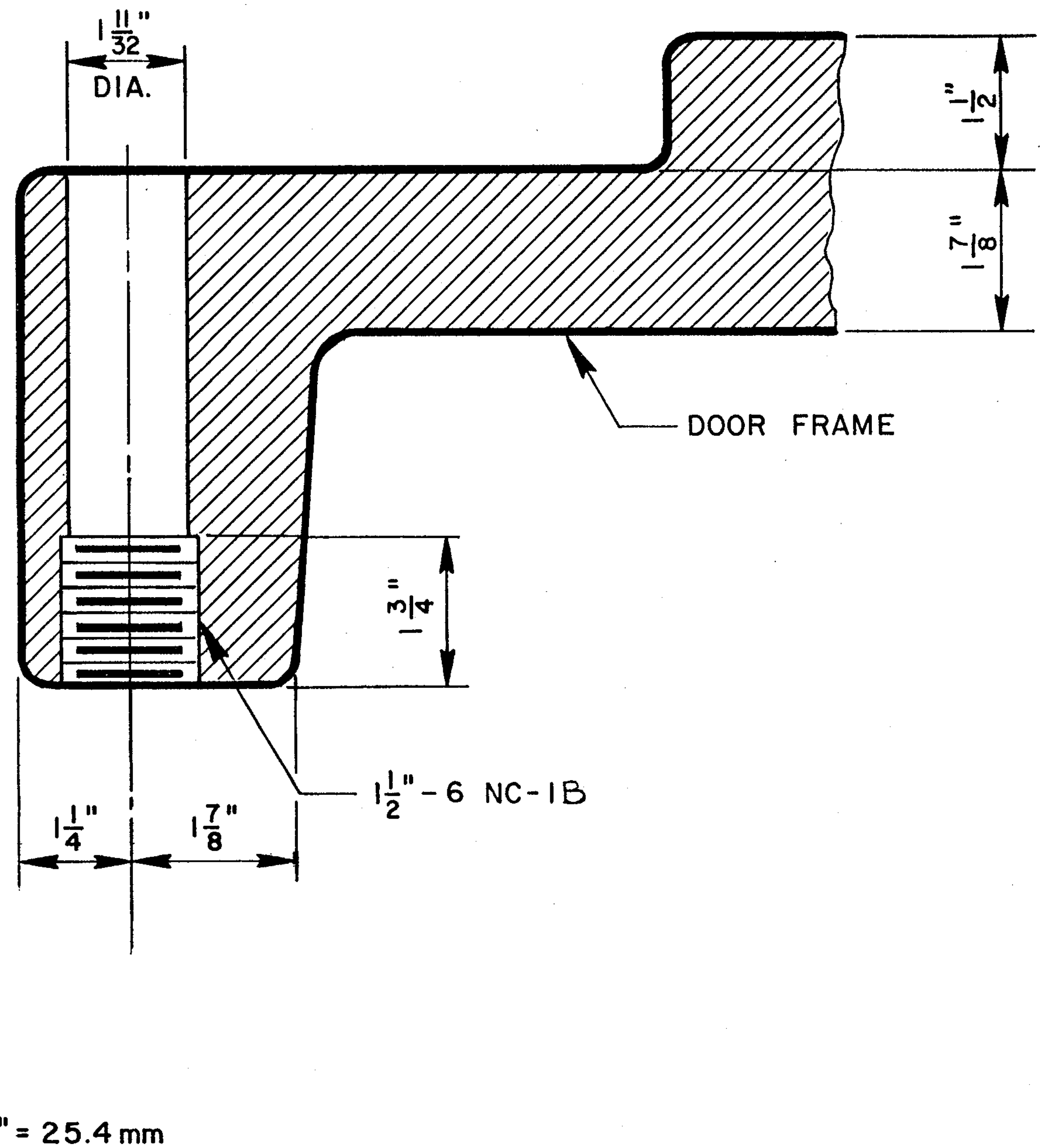
TITLE: DOOR SEAL SEAT FLATNESS TOLERANCE FOR COKE OVEN DOORS

Figure 3-2



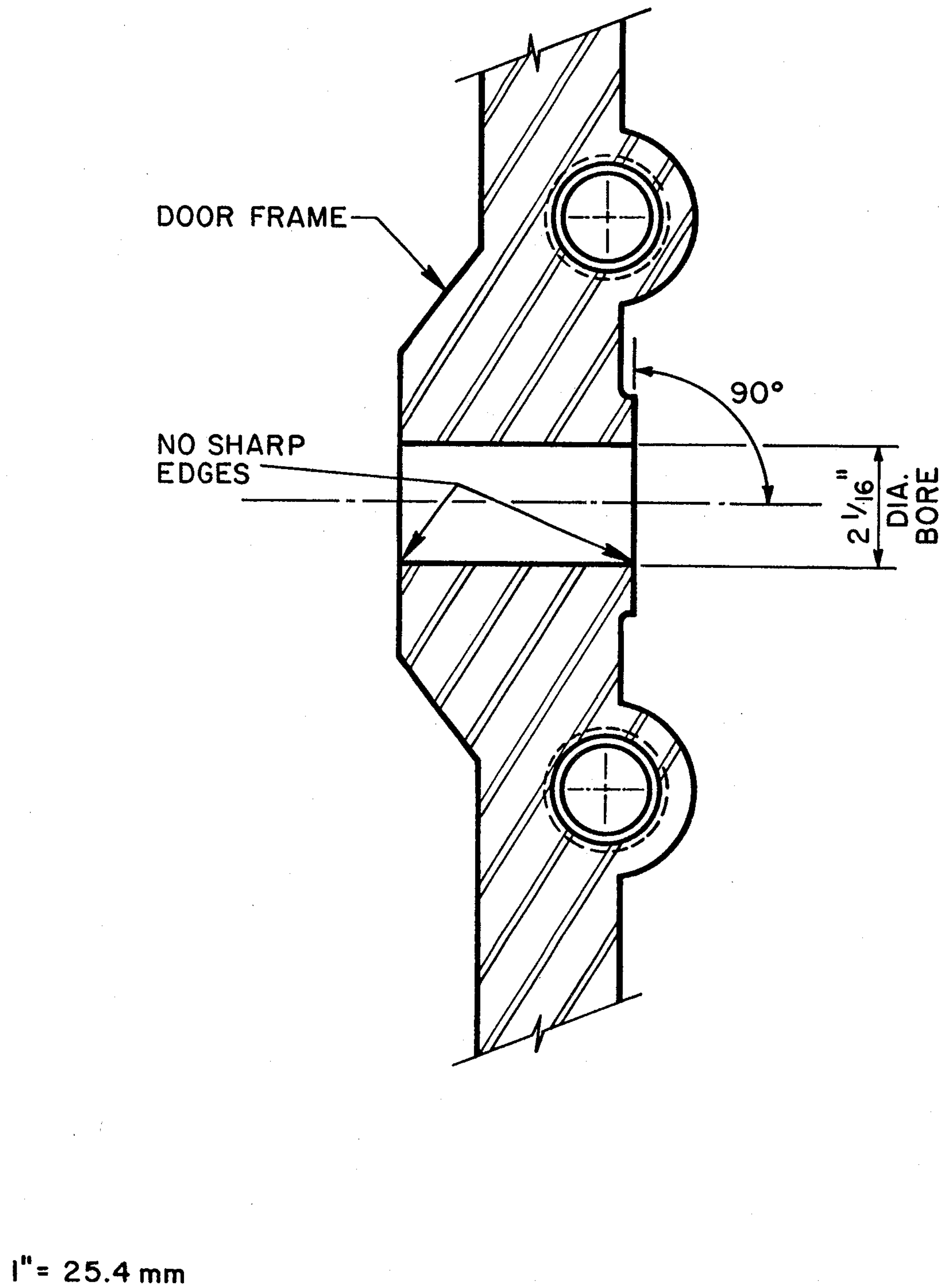
TITLE: METHOD OF MEASURING TWIST IN COKE-OVEN DOOR OVEN FRAMES

Figure 3-3



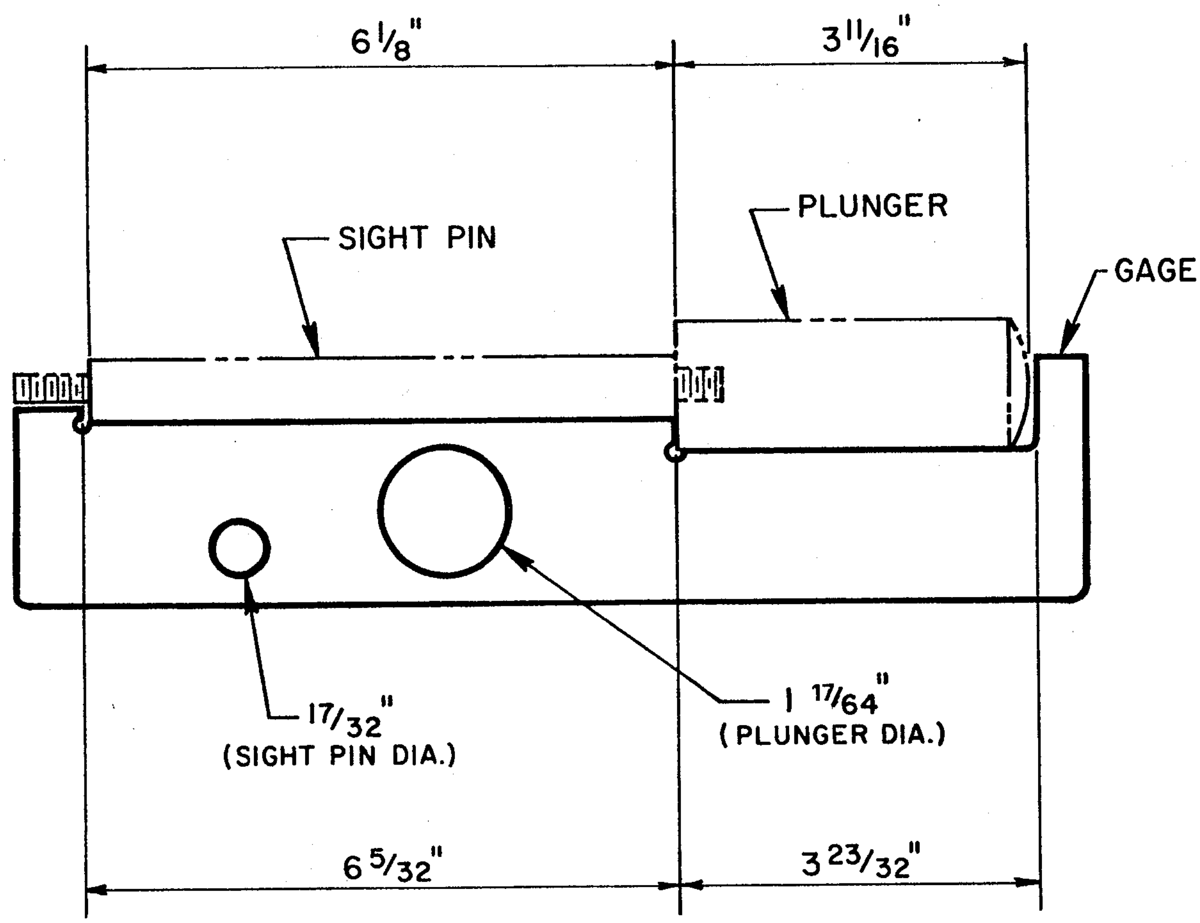
TITLE PLUNGER HOLE FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS — P.S. AND C.S.

Figure 3-4



TITLE: DOOR SUPPORT HOLES FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS

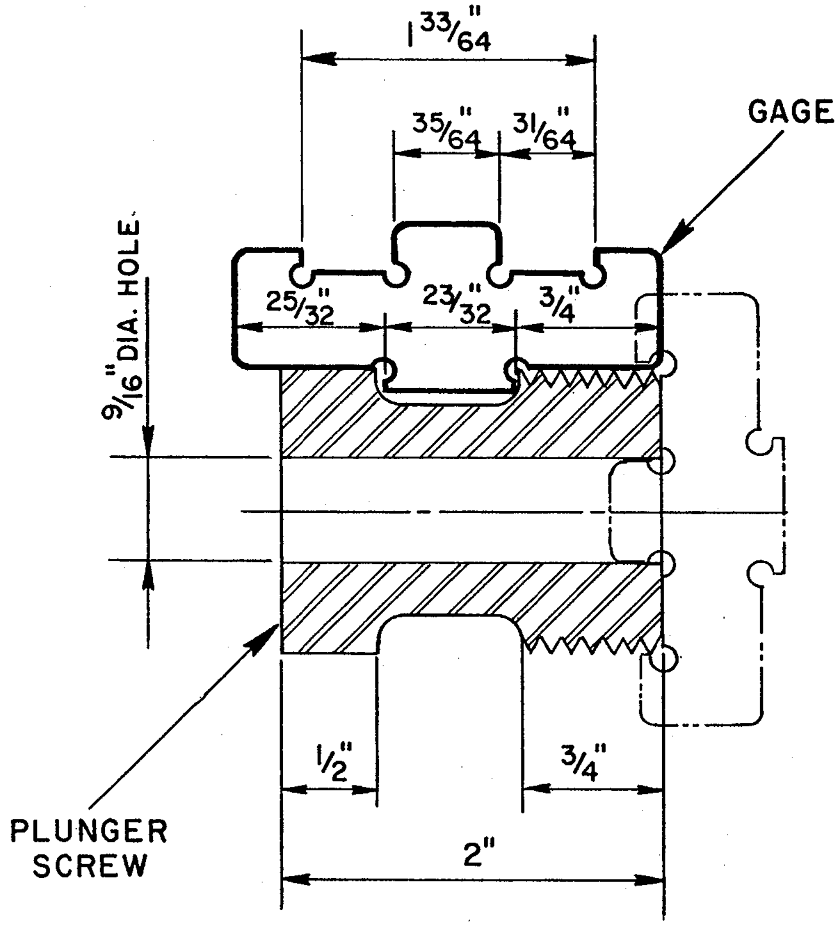
Figure 3-5



1" = 25.4 mm

TITLE: PLUNGER GAGE FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

Figure 3 - 6



1" = 25.4 mm

TITLE PLUNGER SCREW GAGE FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

Figure 3-7

Outside Diameter - 1.156 inches (29.367 mm) must pass through 1.172-inch ID x 4 inches long (29.767 mm ID x 101.6 mm long) tube

Free Height - - - 4.000 inches ± 0.031 inch (101.6 mm ± 0.787 mm)

Solid Height - - - 3.270 inches ± 0.062 inch (83.058 mm ± 1.56 mm)

Total Coils - - - 10.750

Active Coils - - - 8.750

Load Solid - - - - 1593 lb ± 150 lb (7085 N ± 667 N)

Load at 3.500 inches (89 mm) - - - - - - 1100 lb ± 90 lb (4893 N ± 400 N)

Spring Constant at 3.5 inches - - - - 2200 lbs/in. (0.385 kN/mm)

Wire Diameter - - 0.300 inch (7.62 mm)

Material: 17-7 Stainless Steel, Condition CH-900

Ends Squared and Ground

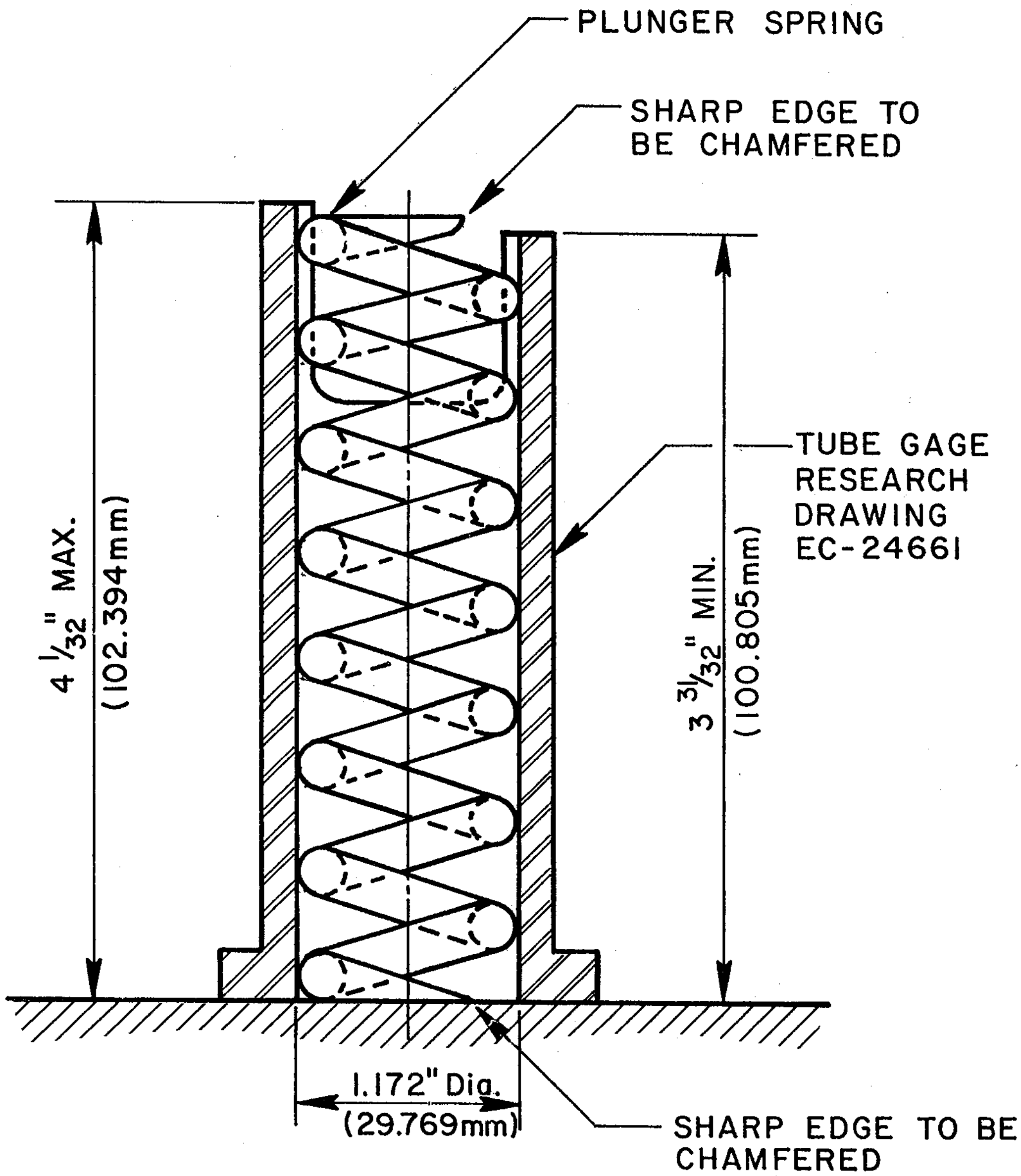
Squareness in Free Position = ± 2°

Left Hand Wound

Note: Ground ends of springs to have sharp edges on O.D. removed (approximately 1/32 inch or 0.787 mm).

SPECIFICATIONS FOR PLUNGER SPRINGS

Figure 3-8

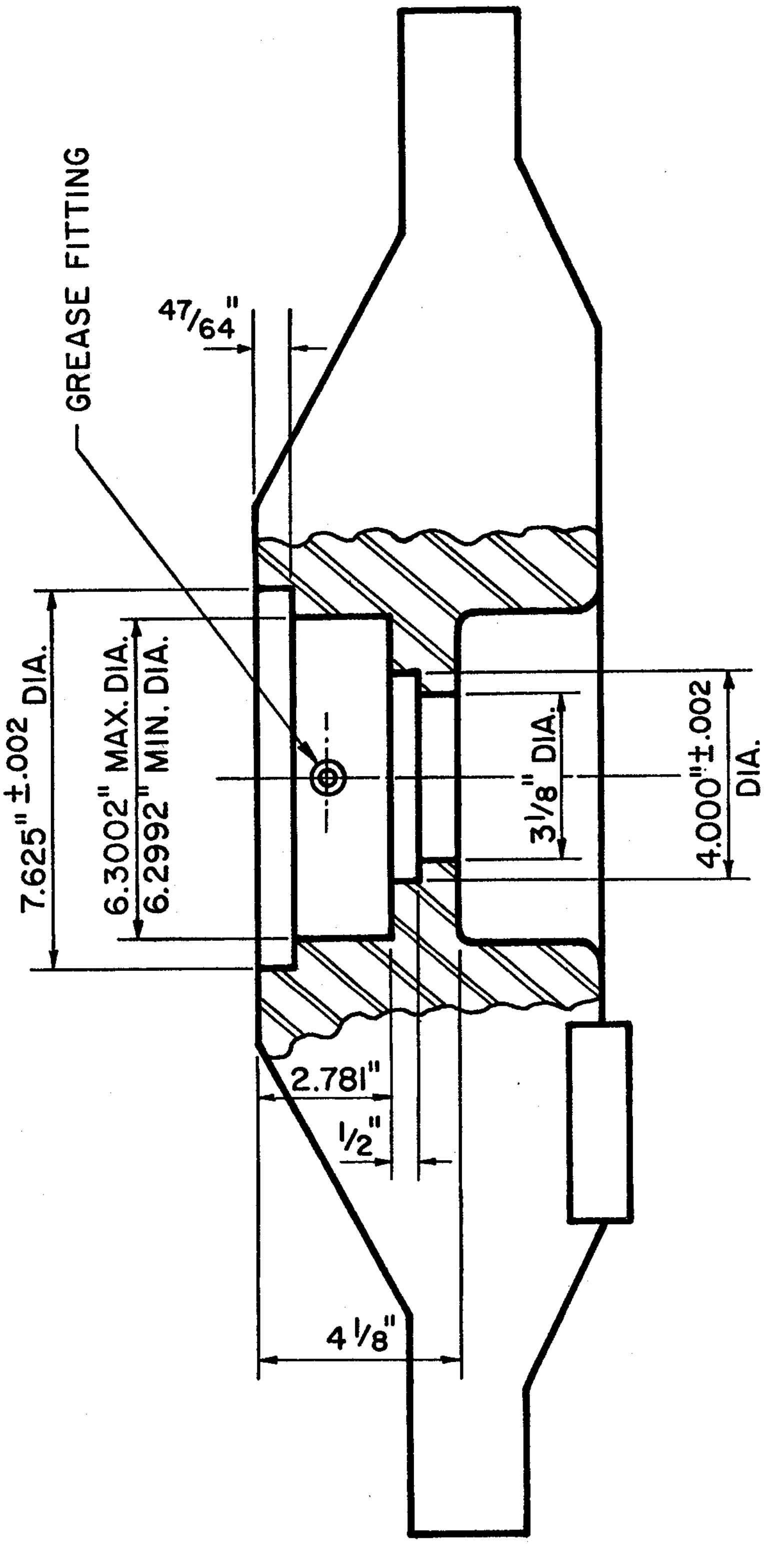


Note: SPRING MUST SLIDE FREELY INTO GAGE.

1" = 25.4 mm

TITLE: PLUNGER-SPRING GAGE FOR USS-2 COKE OVEN DOORS

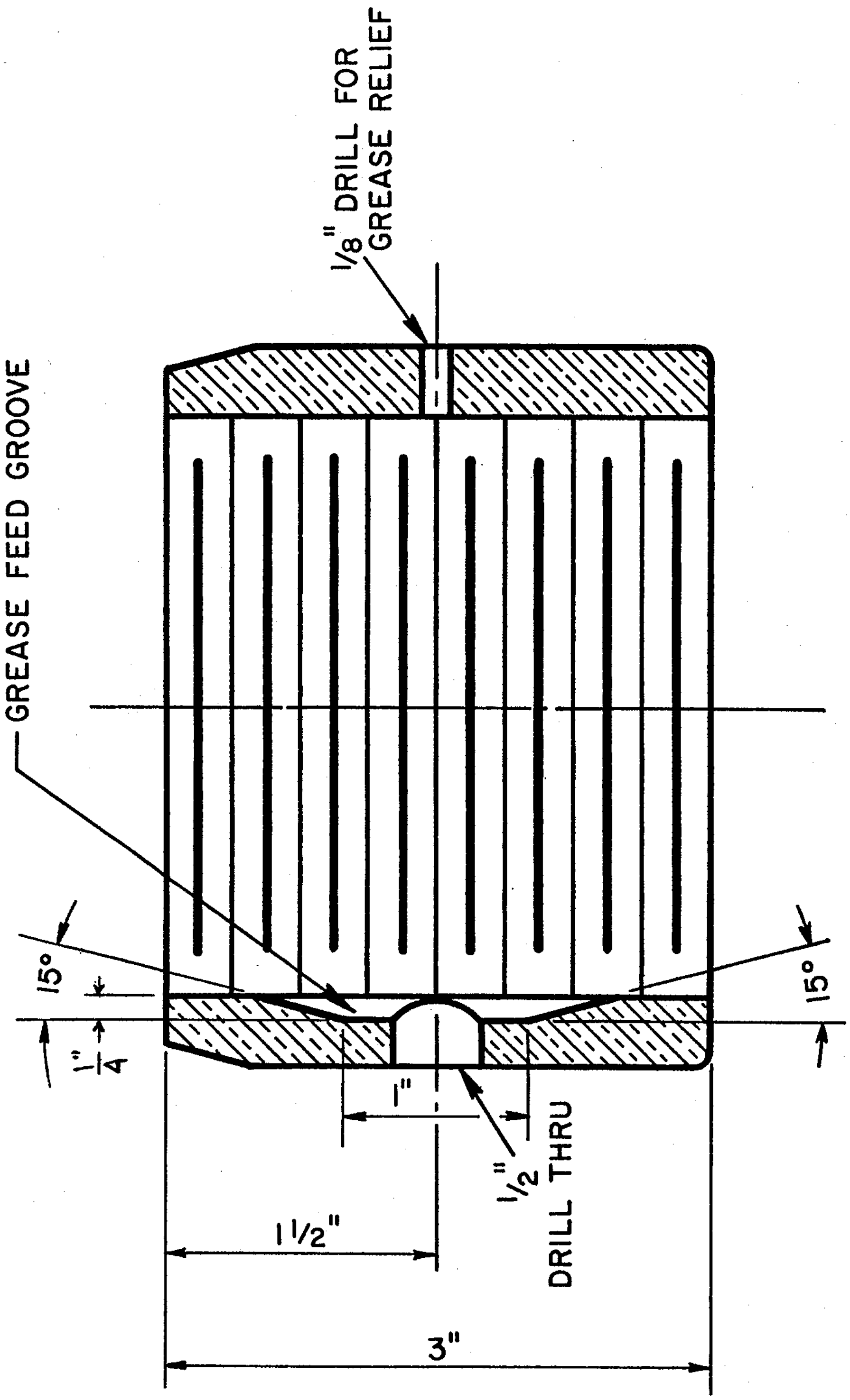
Figure 3-9



1" = 25.4mm

TITLE: LATCH BORE DIMENSIONS FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

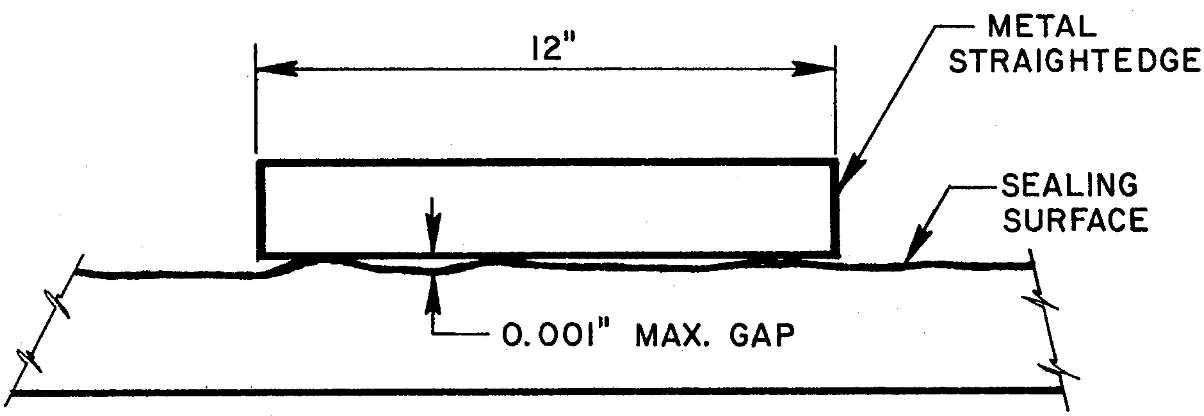
Figure 3-10



1" = 25.4 mm

TITLE: LUBRICATION HOLES FOR LATCH BRACKET BUSHING FOR USS-2 COKE-OVEN DOORS AT GENEVA WORKS

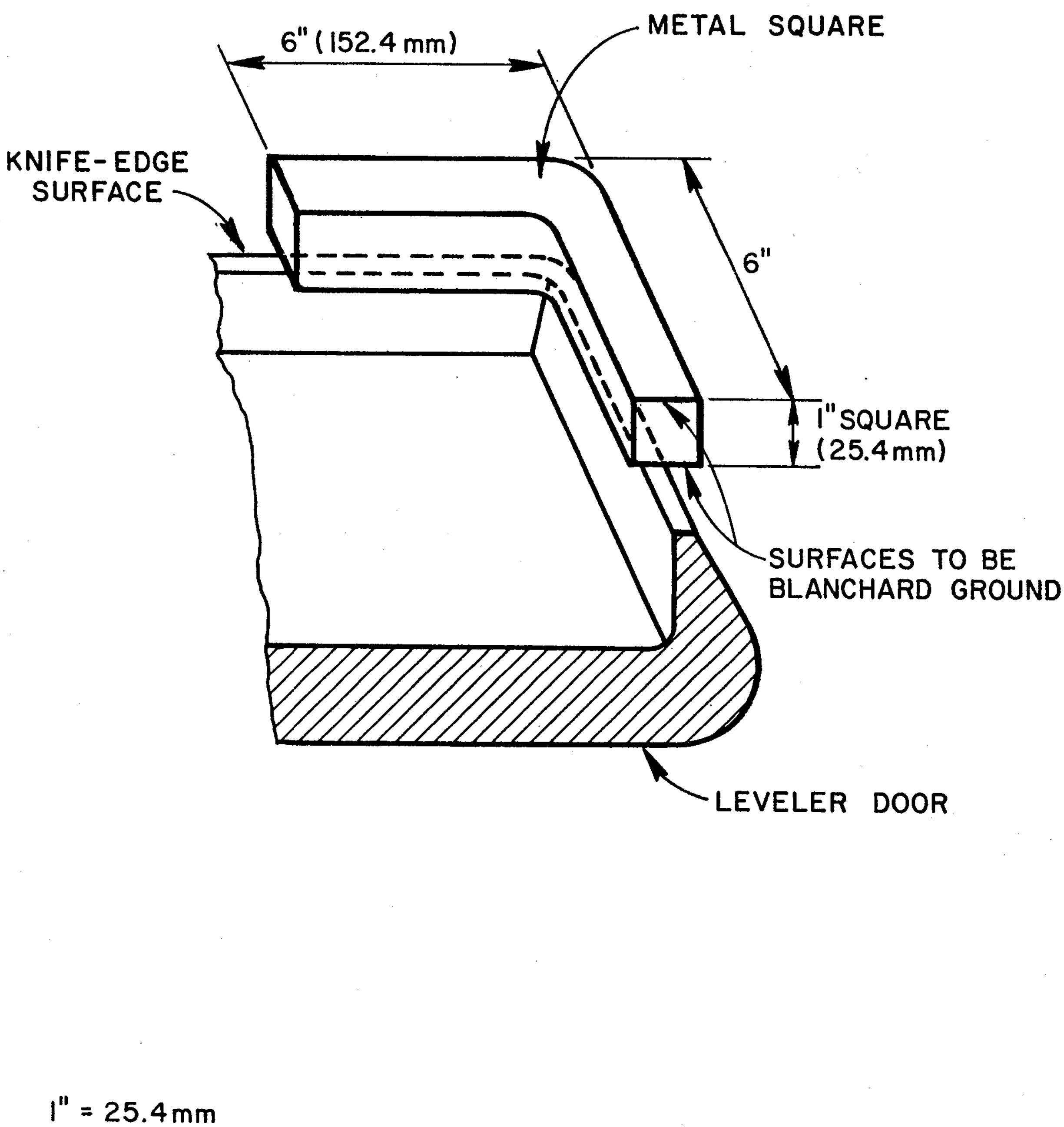
Figure 3 - 11



1" = 25.4 mm

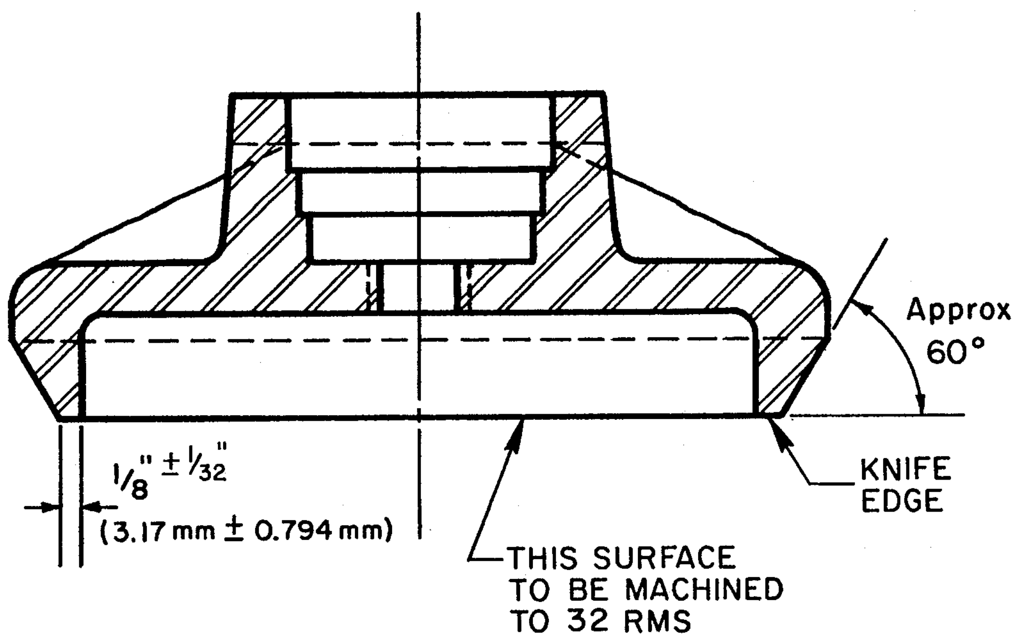
TITLE: LEVELER DOOR AND SEAT SEALING SURFACE WAVINESS AND FLATNESS TOLERANCE FOR USS-2 COKE OVEN DOORS

Figure 3-12



TITLE: METHOD FOR CHECKING THAT LEVELER DOOR KNIFE-EDGE SURFACES LIE IN THE SAME PLANE

Figure 3-13



1" = 25.4mm

TITLE: LEVELER DOOR KNIFE EDGE FOR USS-2 COKE-OVEN DOOR AT GENEVA WORKS

Figure 3 - 14

Outside Diameter - - - - - - - - -	2.937 inches ± 0.031 inch (74.6 mm ± 0.79 mm)
Free Height - - - - - - - - - - -	4.687 inches ± 0.031 inch (119.6 mm ± 0.79 mm)
Solid Height - - - - - - - - - - -	3.875 inches ± 0.062 inch (98.4 mm ± 1.58 mm)
Total Coils - - - - - - - - - - -	5.6 (Approximate)
Active Coils - - - - - - - - - - -	3.6 (Approximate)
Load Solid - - - - - - - - - - - -	5147 lb ± 250 lb (22.9 kN ± 1.1 kN)
Load at 4.250 inches (107.9 mm)-	2700 lb ± 200 lb (12.0 kN ± 0.9 kN)
Spring Constant at 4.250 - - - -	6178 lb/inch (1.08 kN/mm)
Wire Diameter - - - - - - - - - -	0.687 inch (17.462 mm)
Material - - - - - - - - - - - - -	17-4 pH Stainless Steel

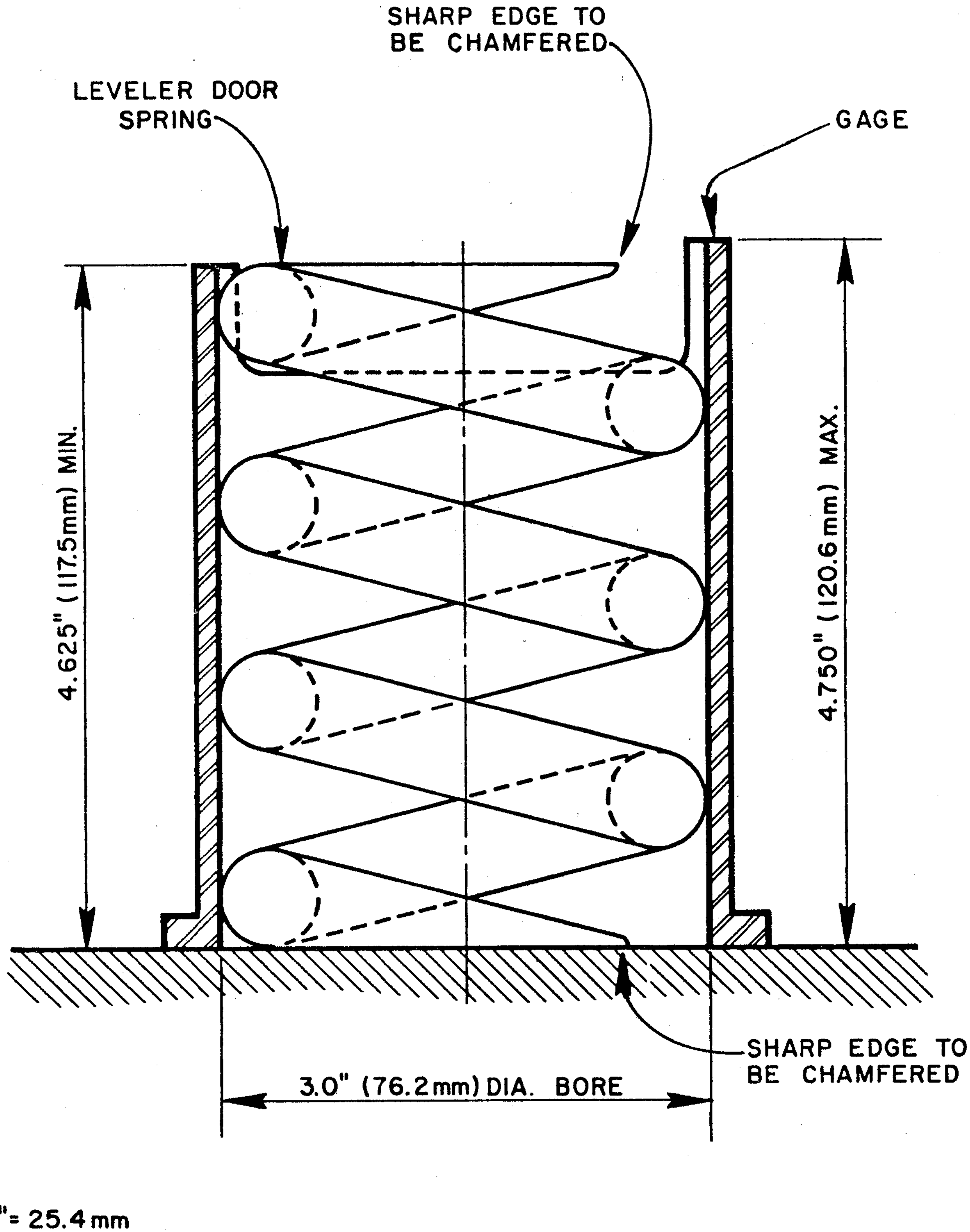
Ends Squared and Ground

Squareness in Free Position = 2.5°

Shearing Cut-off to be Chamfered

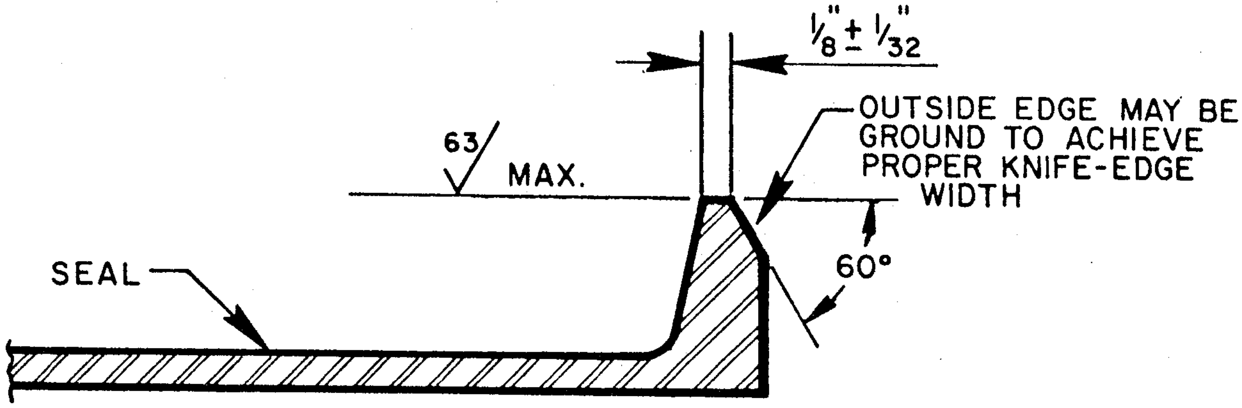
SPECIFICATIONS FOR LEVELER DOOR SPRINGS

Figure 3-15



TITLE LEVELER DOOR SPRING GAGE FOR USS-2 DOORS

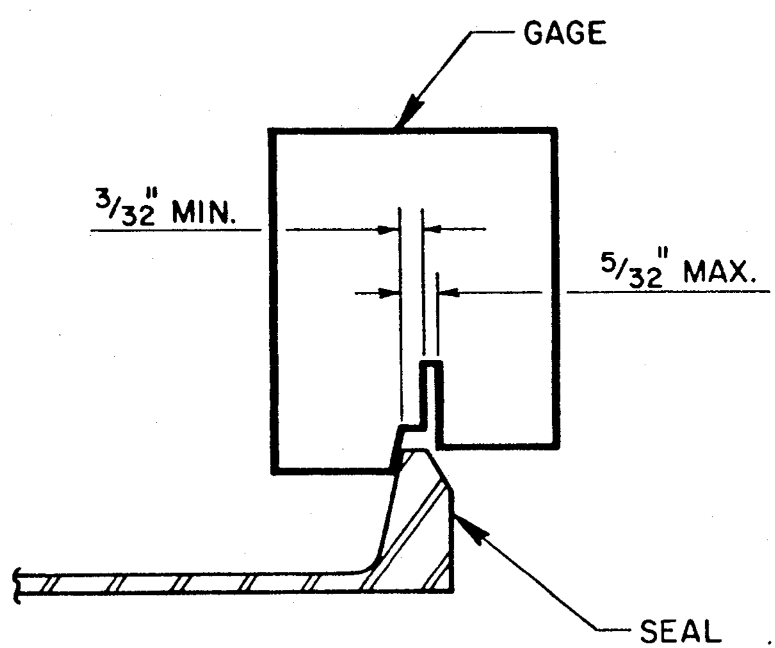
Figure 3-16



1" = 25.4mm

TITLE CROSS SECTION OF SEAL FOR USS-2 COKE OVEN DOORS

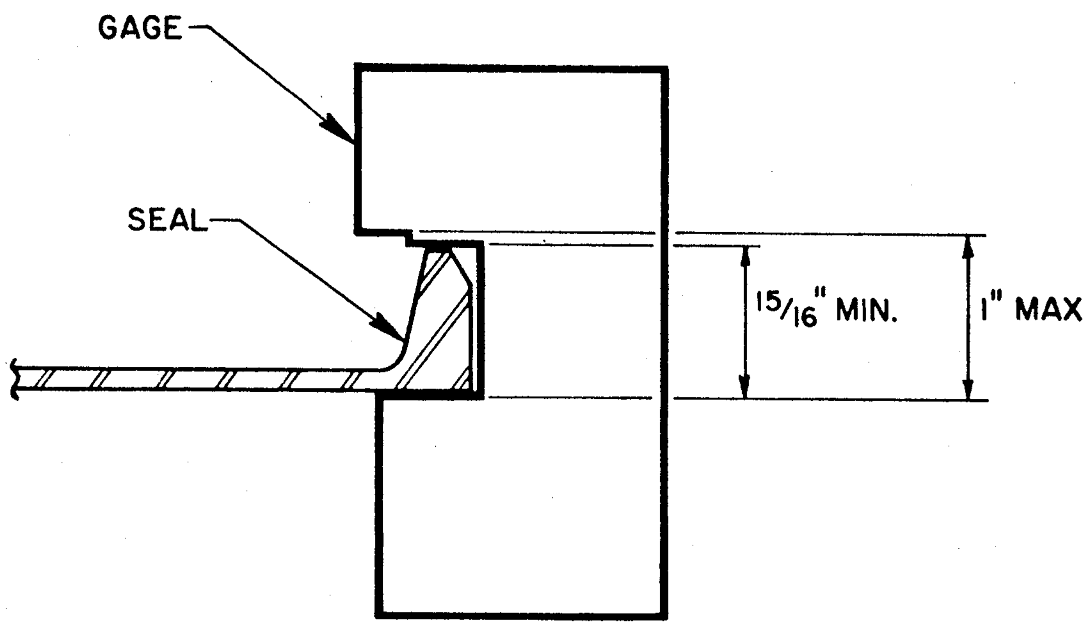
Figure 3-17



1" = 25.4 mm

TITLE: GAGE FOR SEAL KNIFE-EDGE THICKNESS FOR USS-2 COKE OVEN DOORS

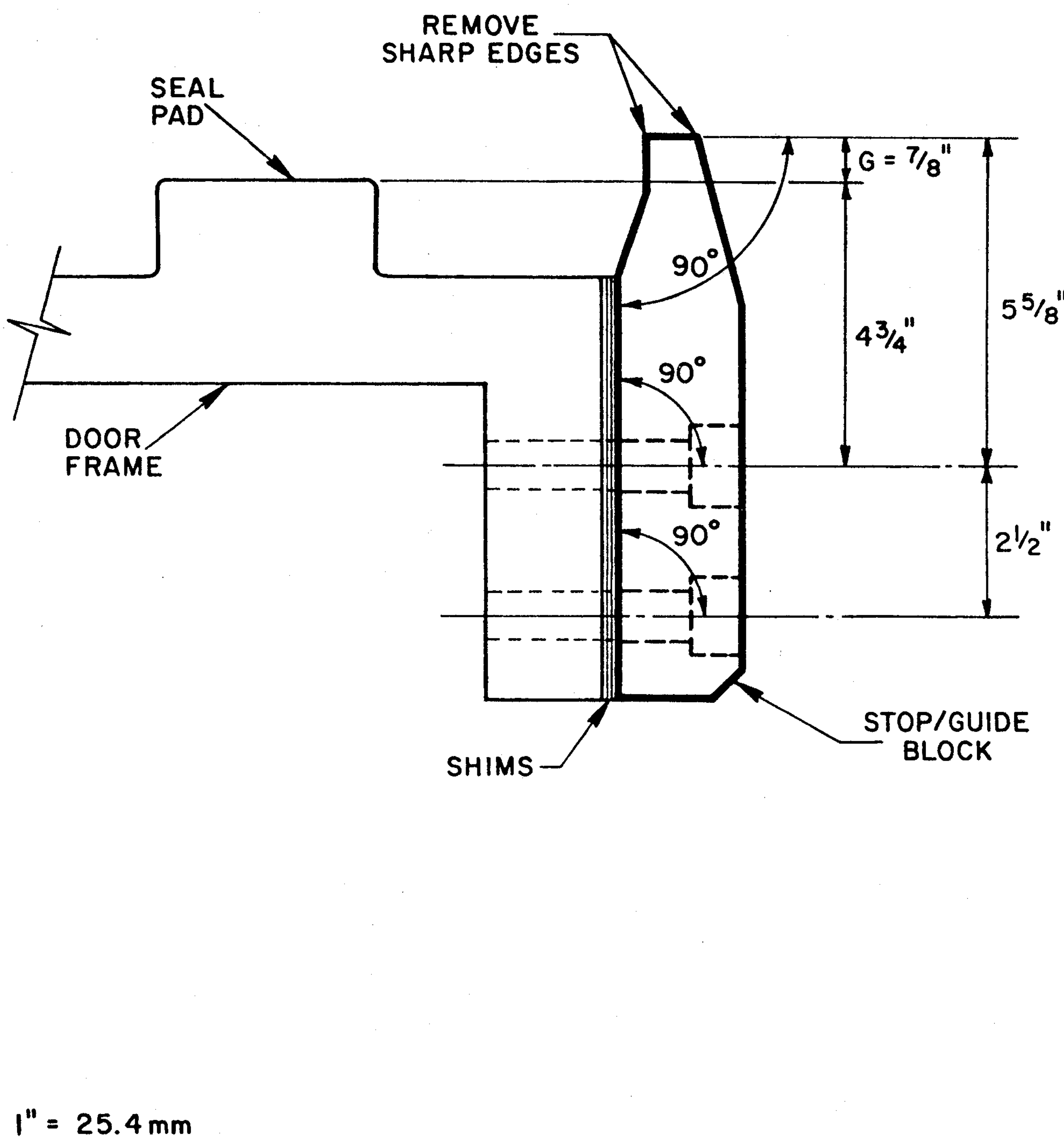
Figure 3-18



1" = 25.4 mm

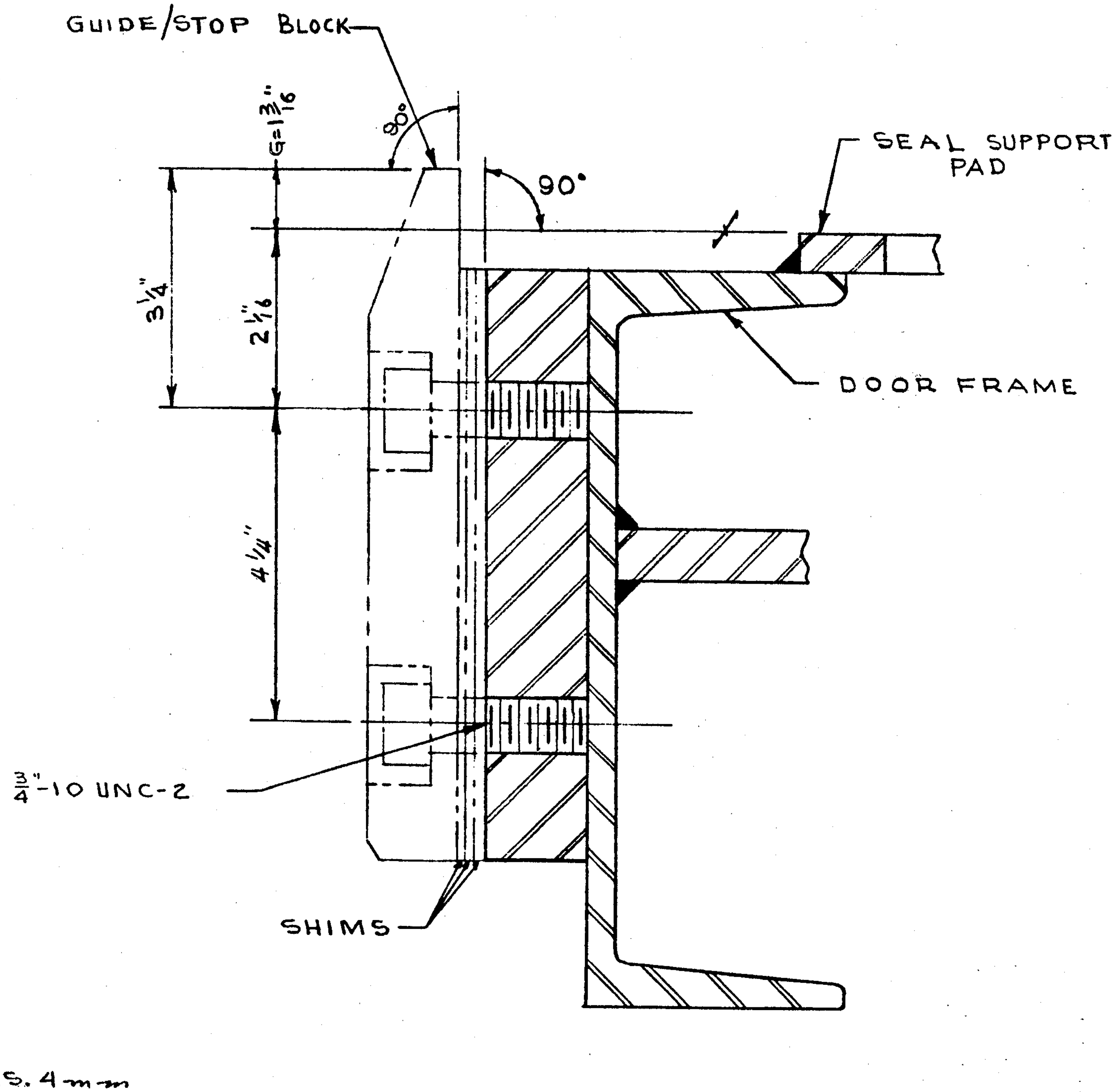
TITLE: SEAL HEIGHT GAGE FOR USS-2 COKE OVEN DOORS

Figure 3-19



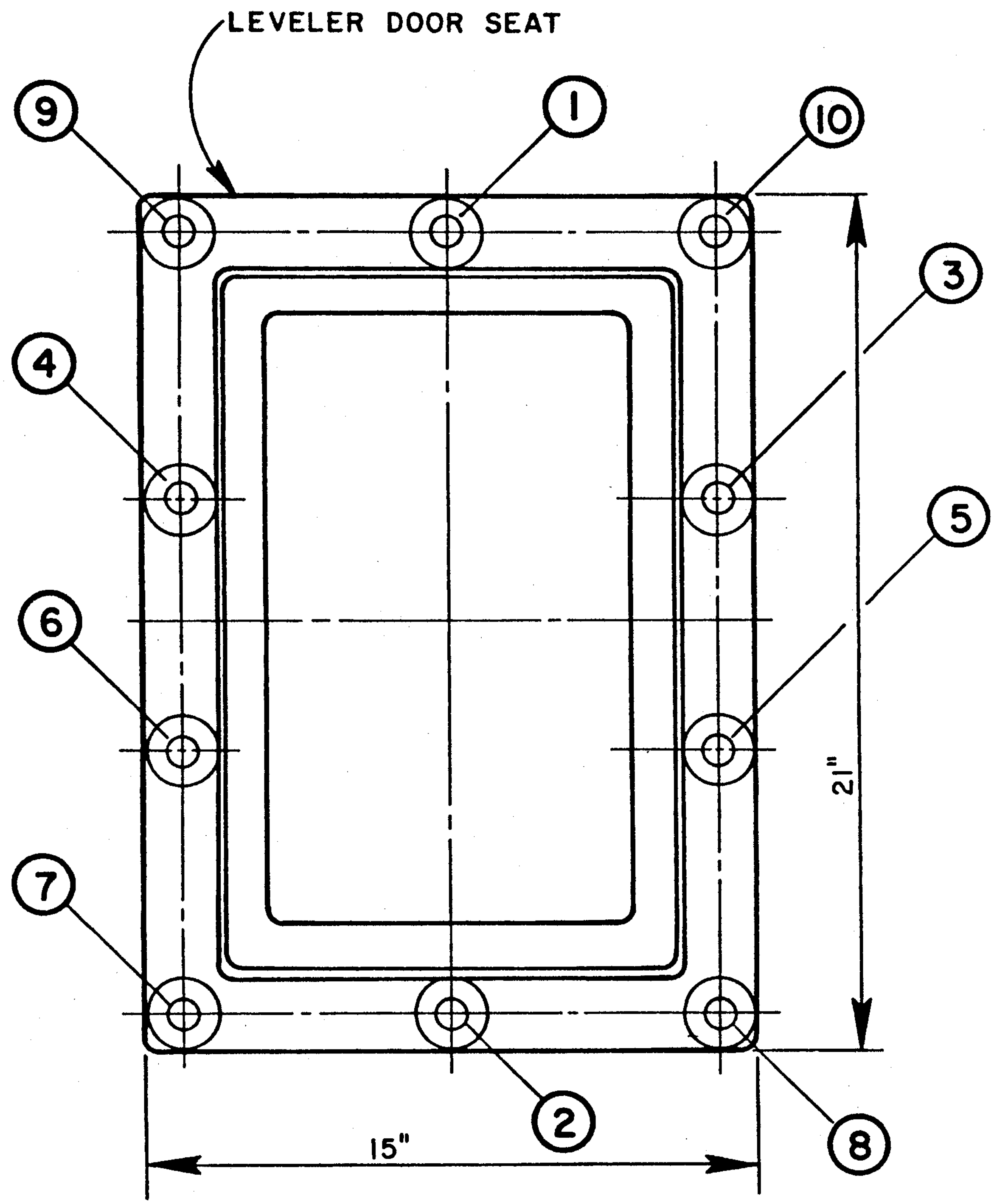
TITLE: STOP/GUIDE BLOCK MOUNTING HOLE LOCATION FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS

Figure 3-20-a



GUIDE/STOP BLOCK MOUNTING HOLES FOR USS-1 COKE-OVEN DOOR, CLAIRTON, WORKS, BATTERIES 1-3

Figure 3-20-b



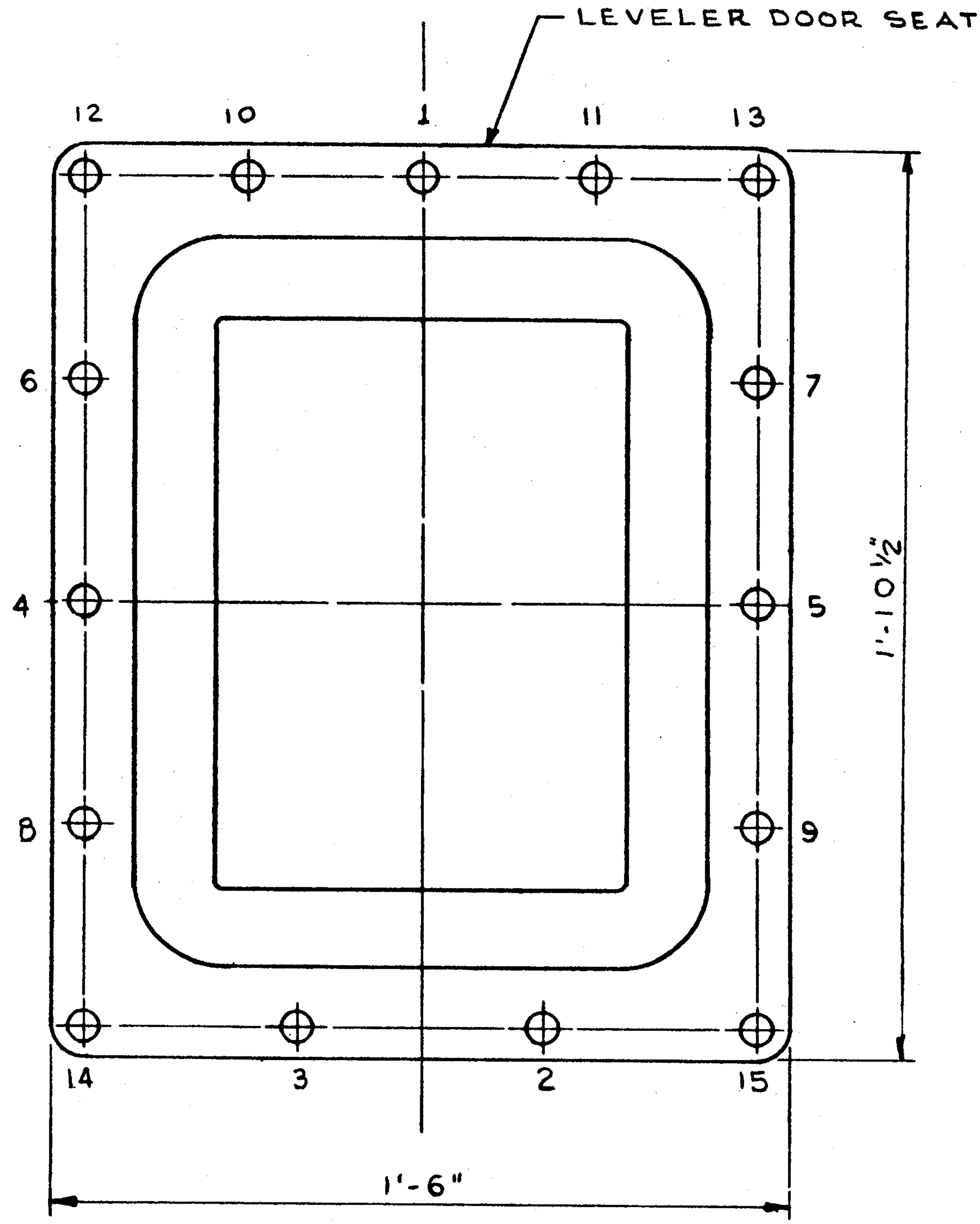
TORQUE ALL CAP BOLTS TO 50 FT. LBS. (67.7 Nm) IN THE SEQUENCE AS SHOWN.

TORQUE VALUES ARE FOR 3/4"–10 UNC CAP BOLTS

1" = 25.4mm

TITLE	TORQUE SEQUENCE FOR LEVELER DOOR SEAT FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

Figure 3-21-a

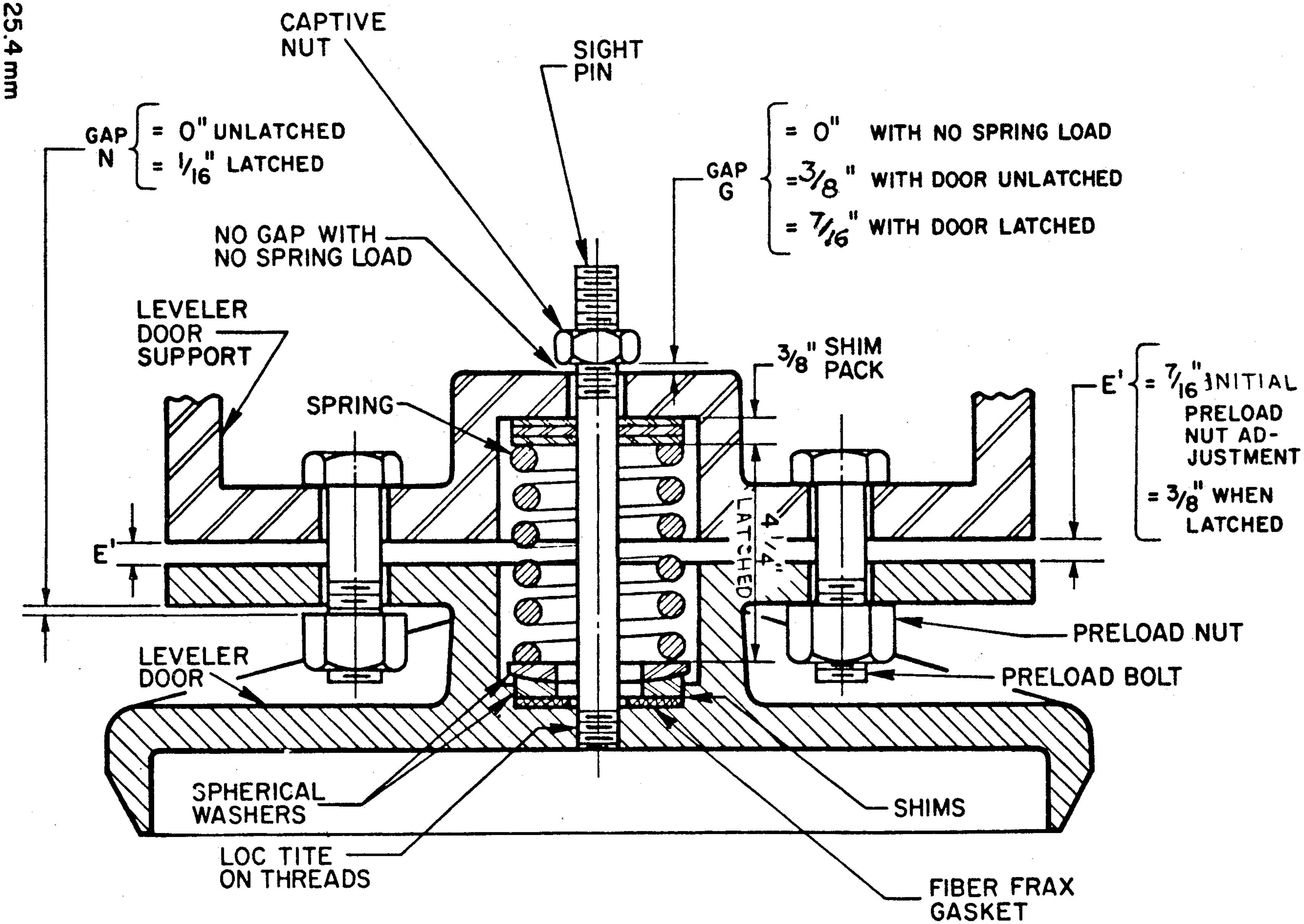


TORQUE ALL BOLTS TO 50 FT.LB. (67.7 Nm) IN THE SEQUENCE SHOWN. TORQUE VALUES ARE FOR 5/8"-11 UNC CAP BOLTS.

TORQUE SEQUENCE FOR LEVELER DOOR SEAT BOLTS, USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

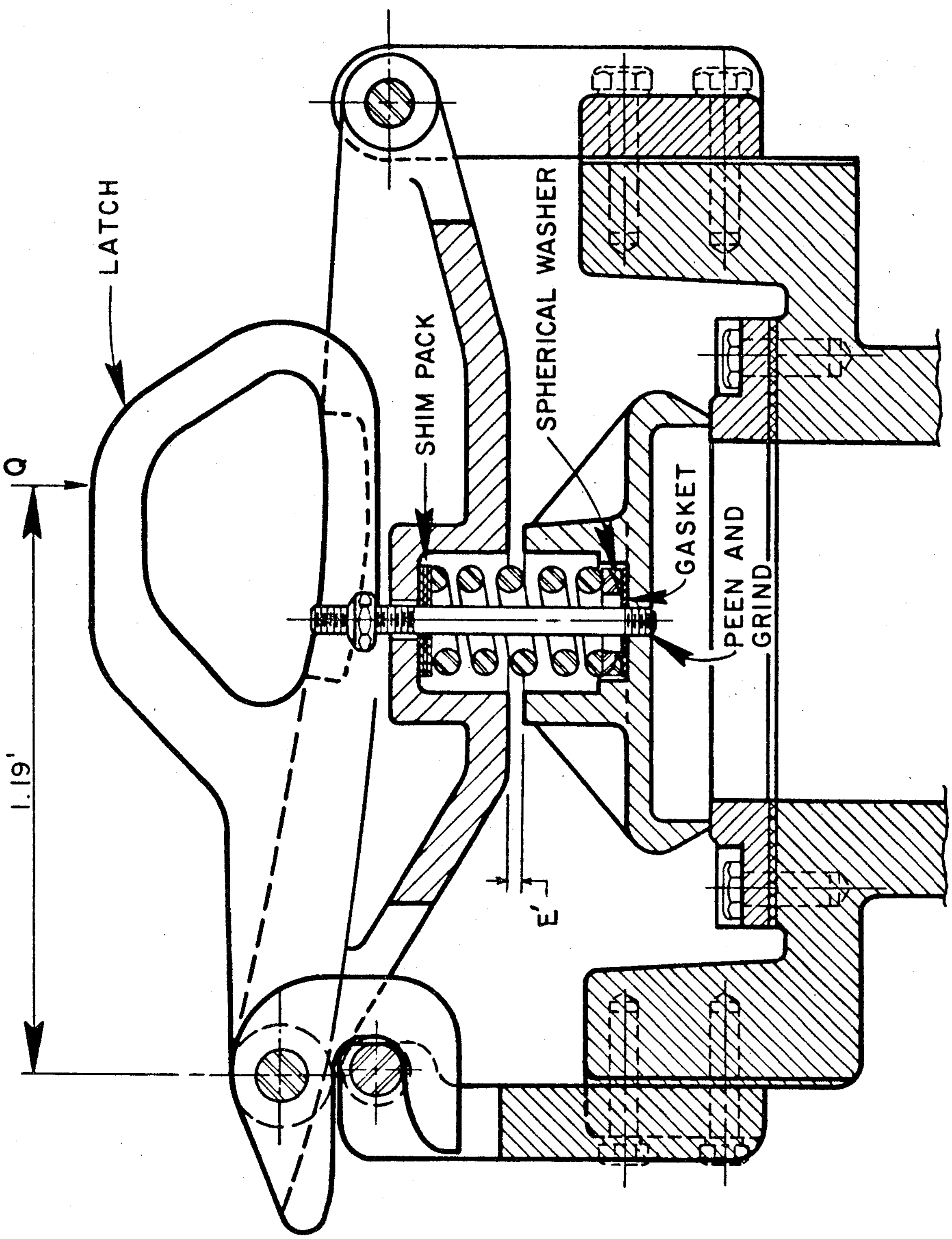
Figure 3-21-b

1" = 25.4 mm



TITLE: PREASSEMBLY OF LEVELER COMPONENTS FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

Figure 3-22

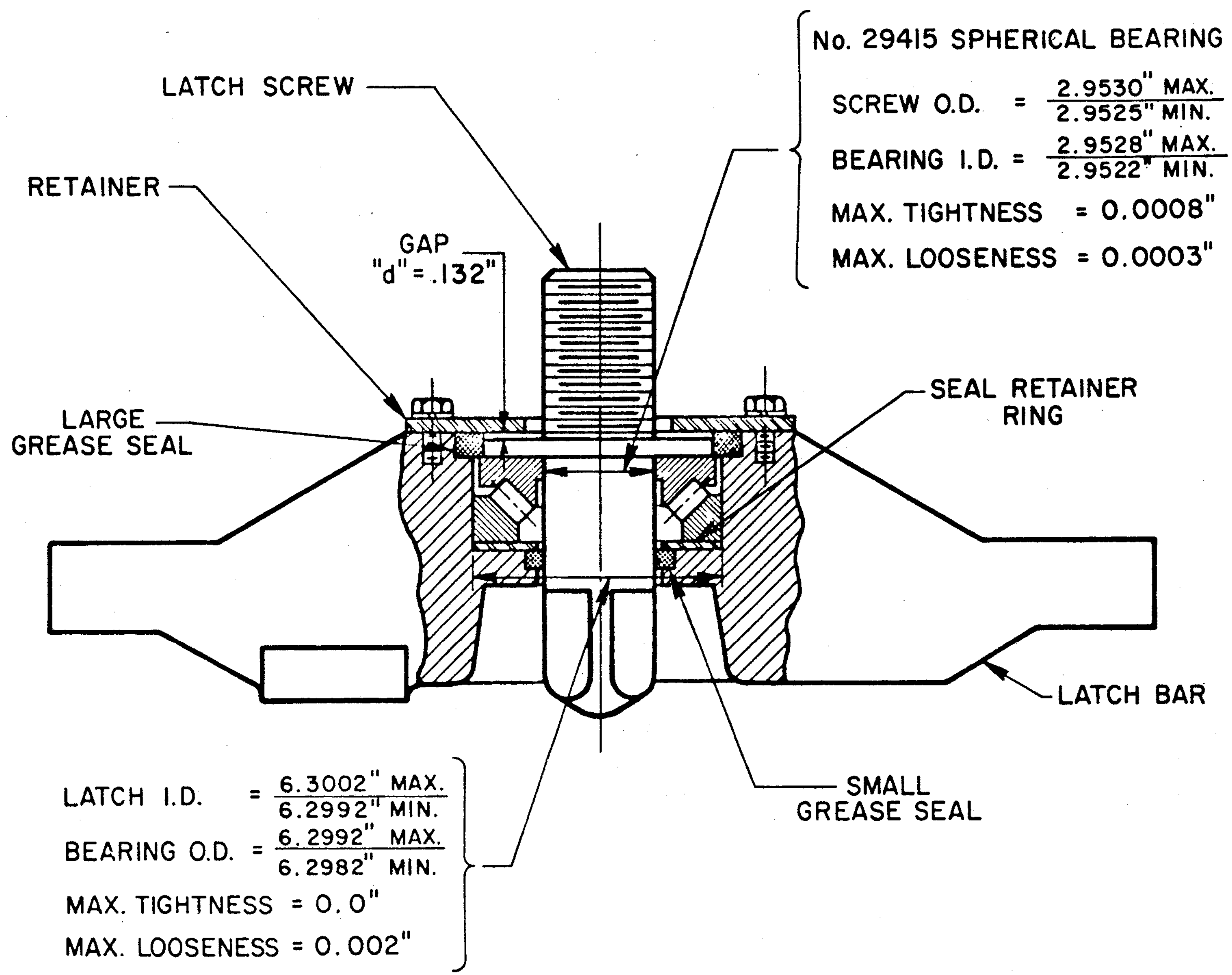


PERIPHERAL LOAD = $\frac{2700 \text{ LBS.}}{52 \text{ IN.}}$ = 51.9 $\frac{\text{LBS.}}{\text{IN.}}$ (9.1 $\frac{\text{N}}{\text{mm}}$)
ON DOOR SEAL EDGE.

1" = 25.4 mm

TITLE: LEVELER DOOR ASSEMBLY FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS

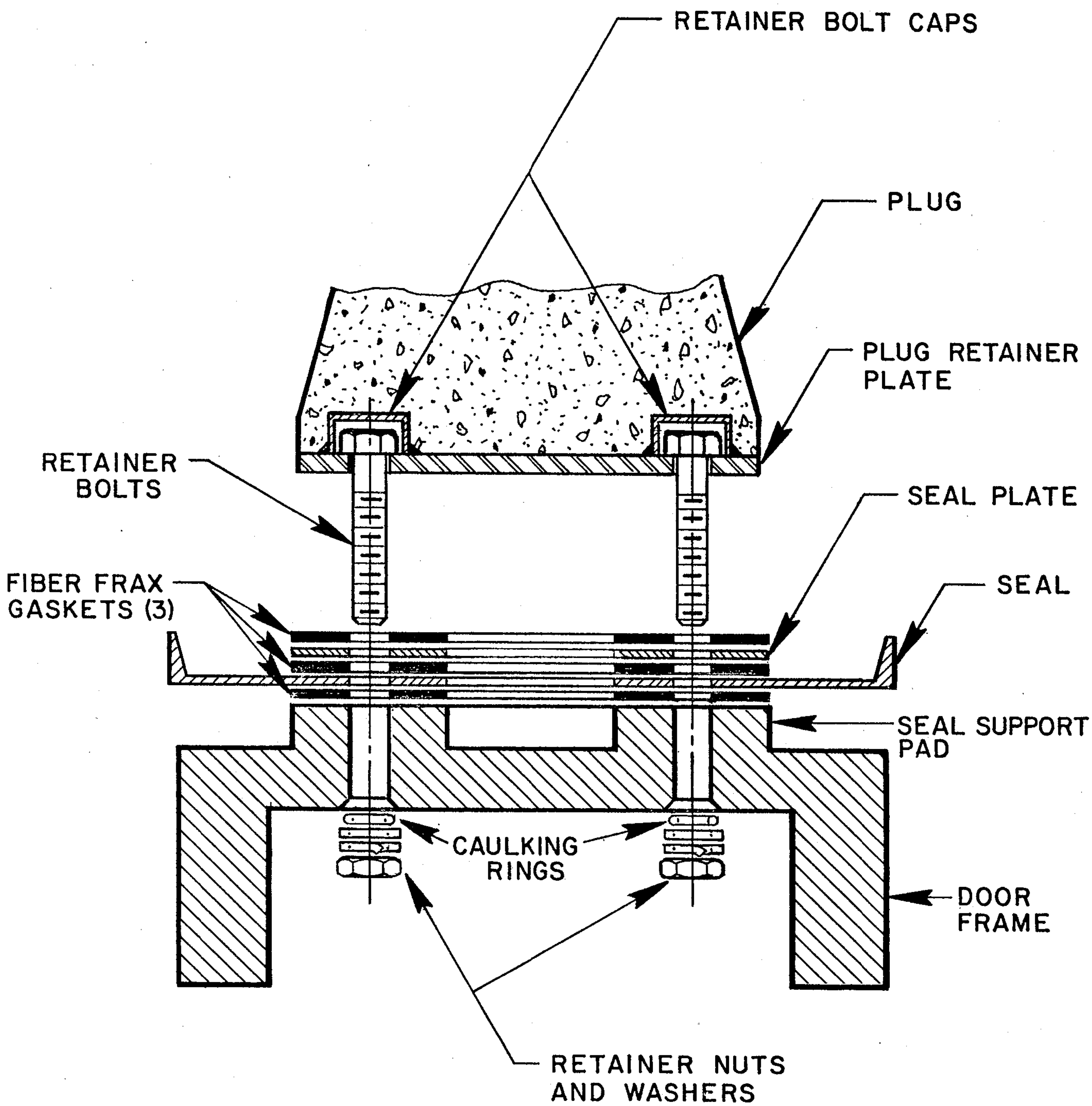
Figure 3-23



1" = 25.4mm

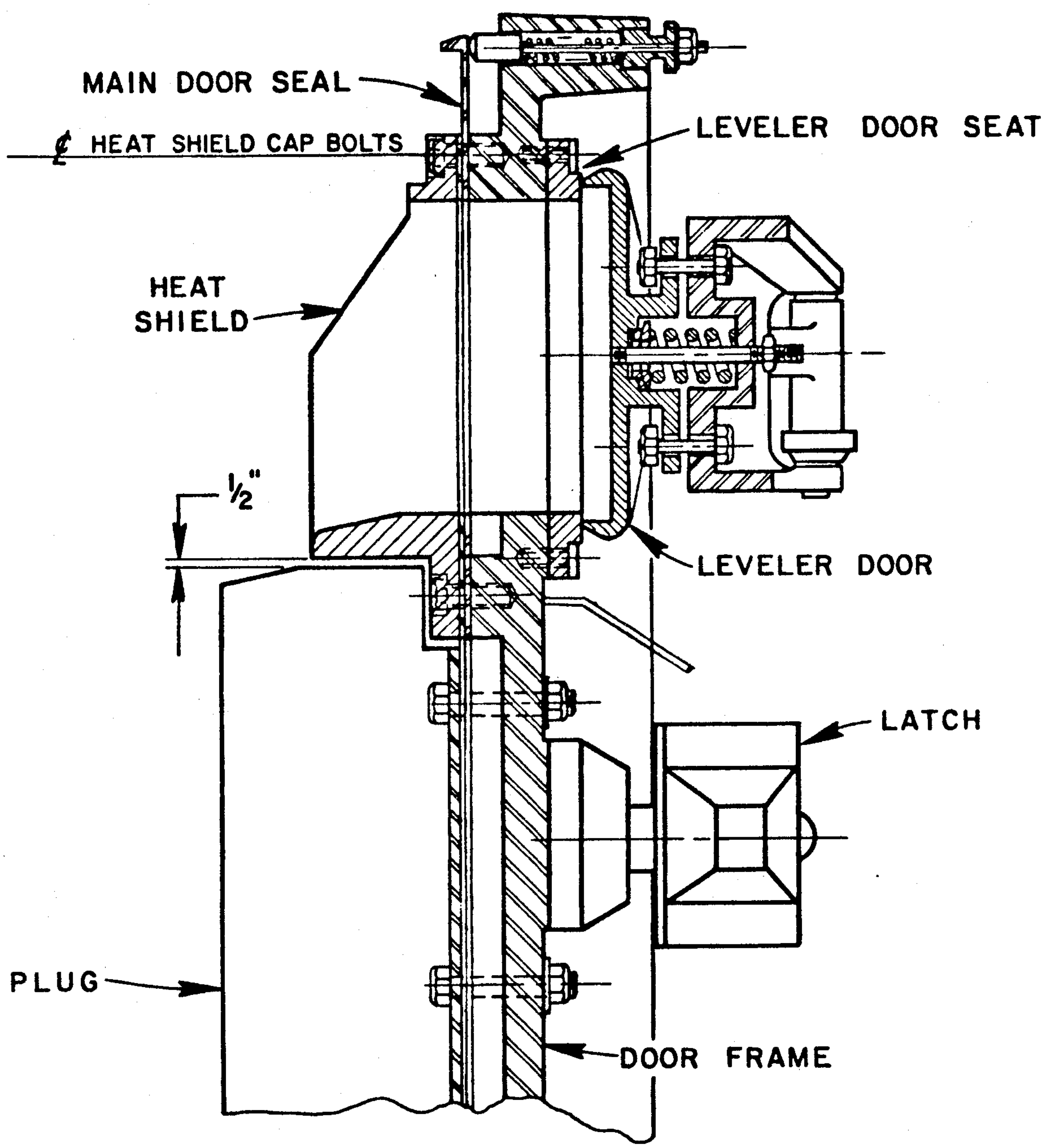
TITLE: LATCH PREASSEMBLY FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS

Figure 3-24



TITLE: ASSEMBLY PROCEDURE FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

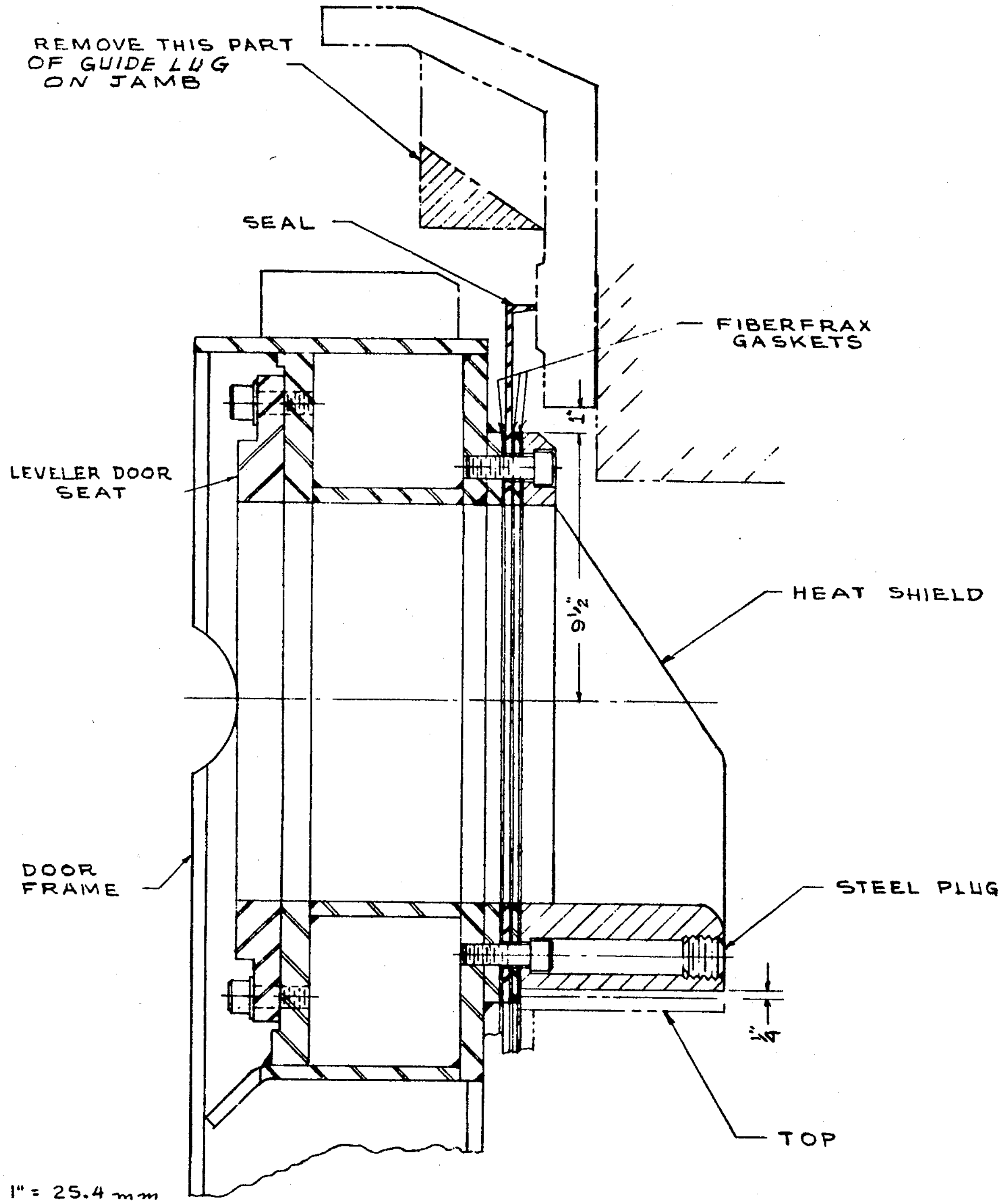
Figure 3-25



1" = 25.4 mm

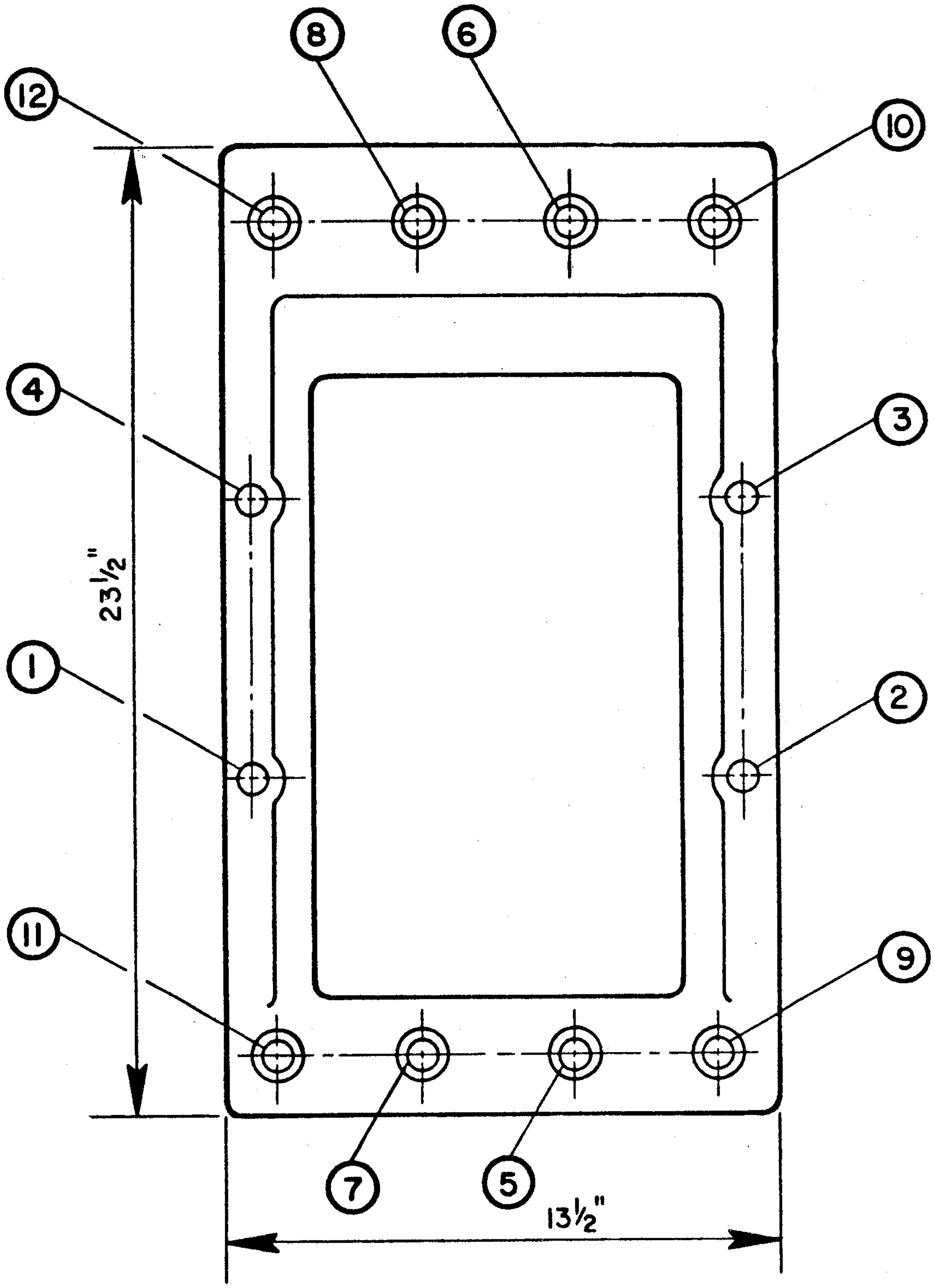
TITLE ASSEMBLY OF TOP PORTION OF USS-2 COKE OVEN DOOR AT GENEVA WORKS – PUSHER SIDE

Figure 3-26-a



ASSEMBLY OF TOP PORTION OF USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 3-26-b



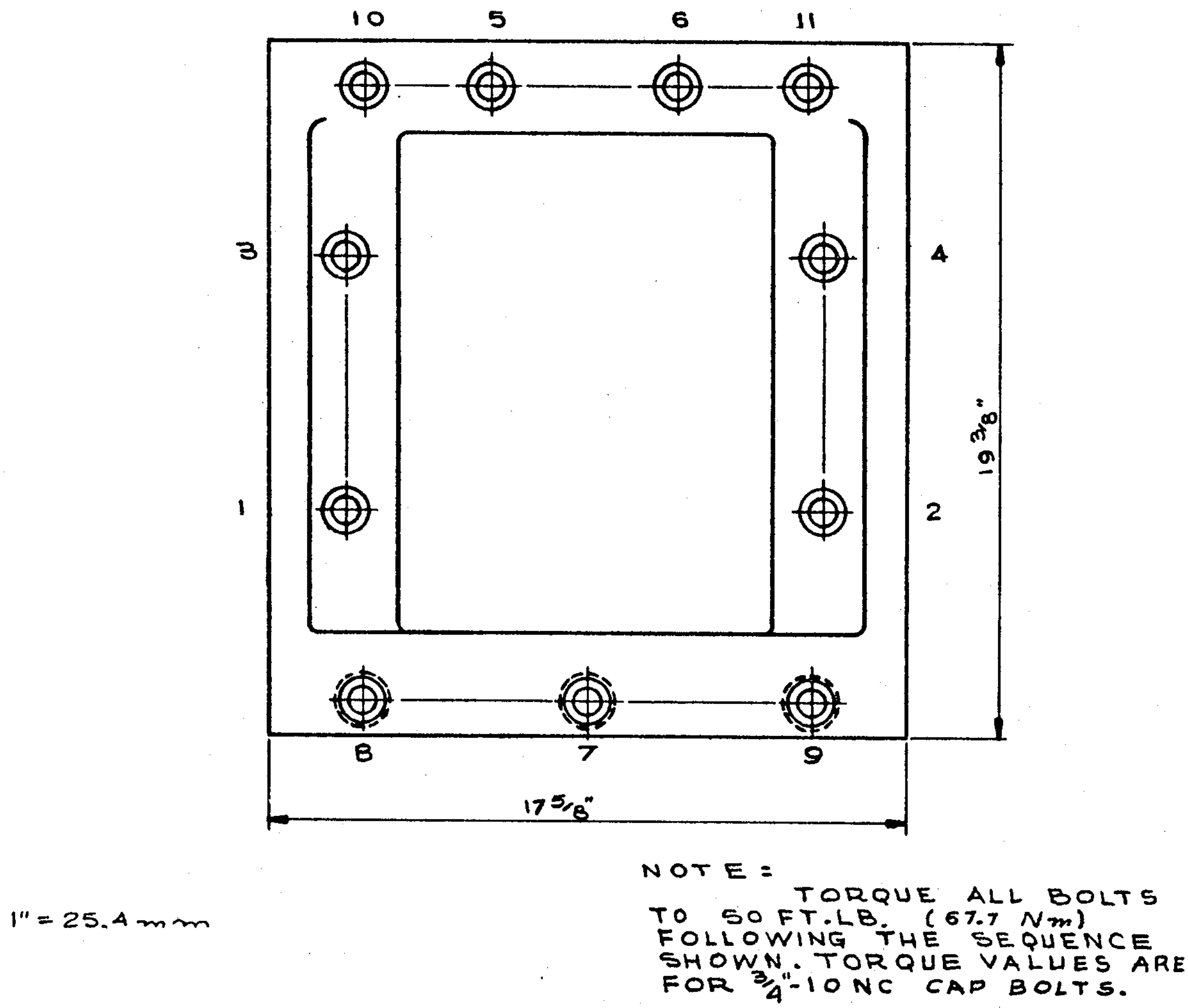
Notes:

TORQUE ALL BOLTS TO 50 FT. LBS (67.7 Nm) FOLLOWING THE SEQUENCE SHOWN. TORQUE VALUES ARE FOR ¾"-10 UNC CAP BOLTS.

1" = 25.4 mm

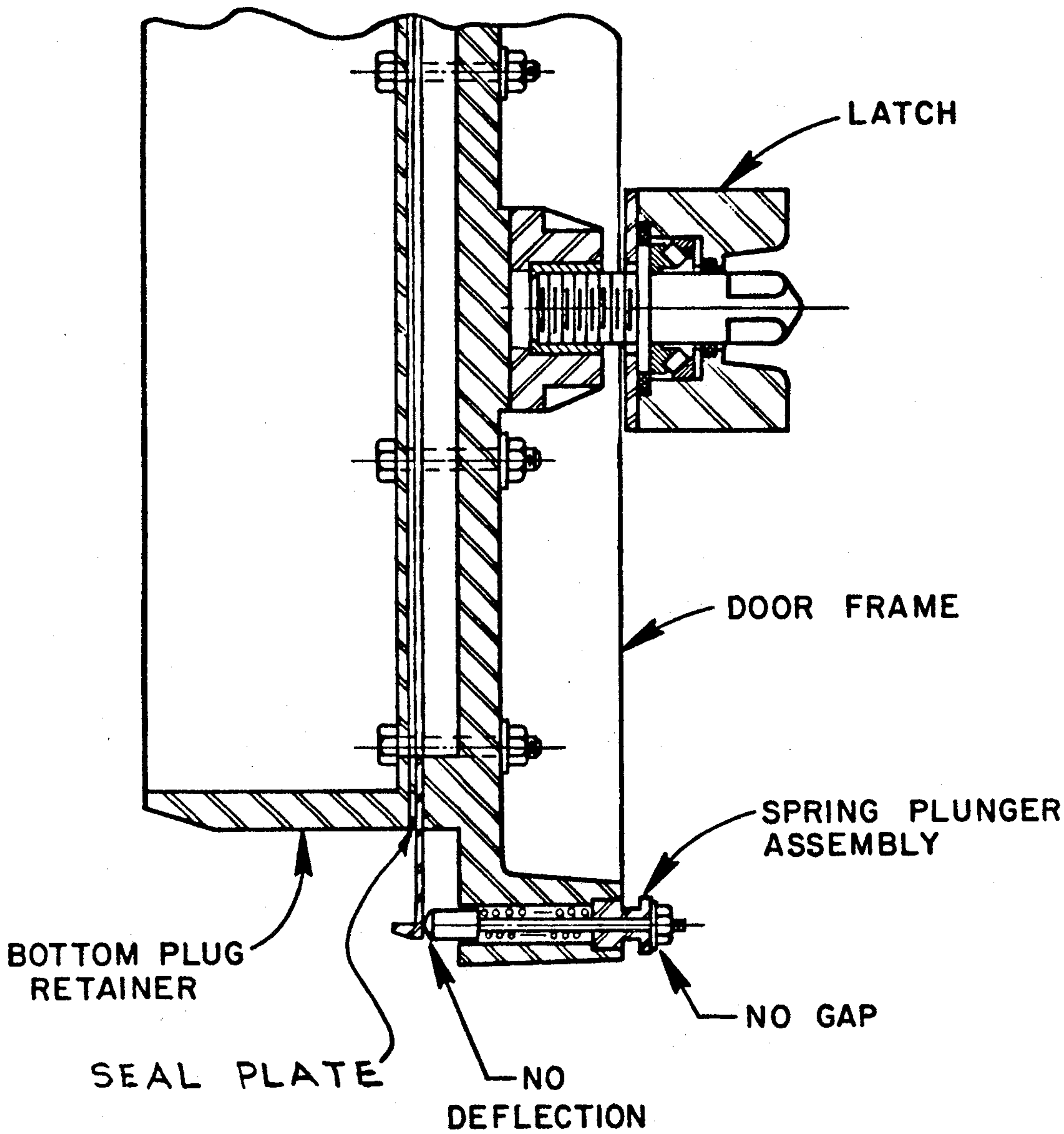
TITLE: LEVELER DOOR HEAT SHIELD BOLT TORQUE SEQUENCE FOR USS-2 COKE OVEN DOOR AT GENEVA WORKS

Figure 3-27-a



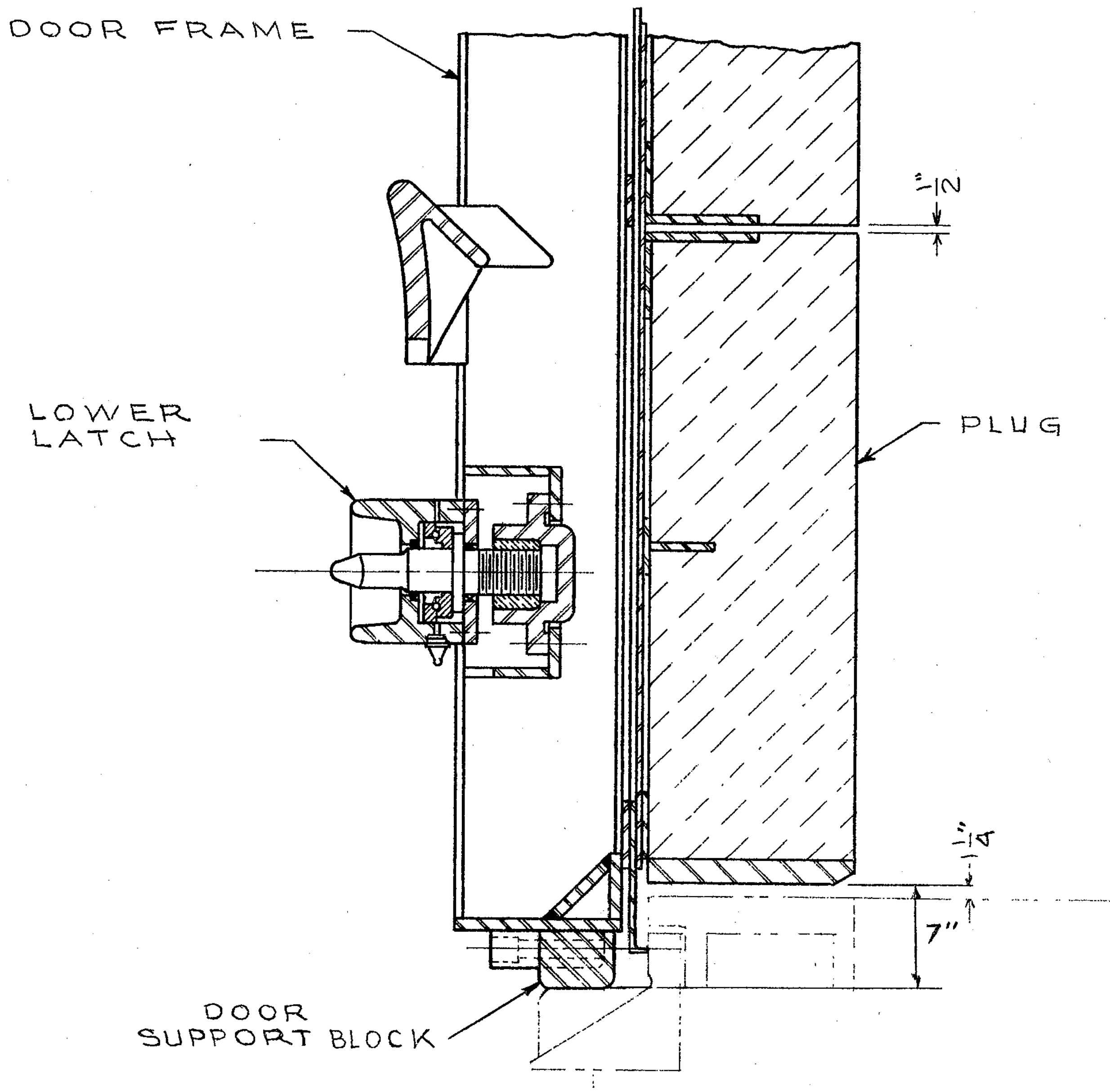
LEVELER-DOOR HEAT-SHIELD BOLT TORQUE SEQUENCE,
USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 3-27-b



TITLE: ASSEMBLY OF BOTTOM PORTION OF USS-2 COKE OVEN DOOR AT GENEVA WORKS - PUSHER SIDE

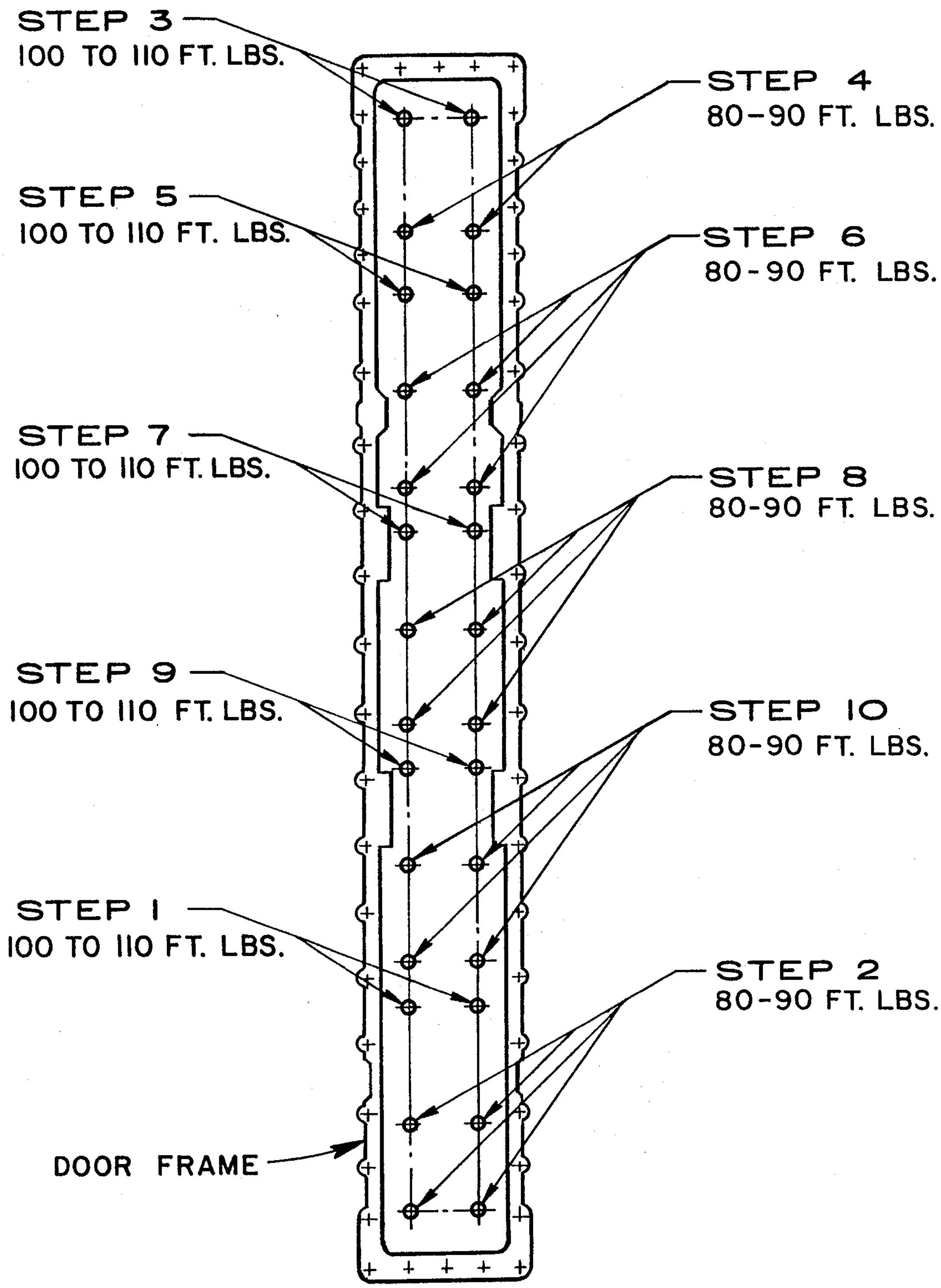
Figure 3-28-a



1" = 25.4 mm

ASSEMBLY OF BOTTOM PORTION OF USS-1 COKE-OVEN DOORS AT CLAIRTON WORKS, BATTERIES 1-3

Figure 3-28-b

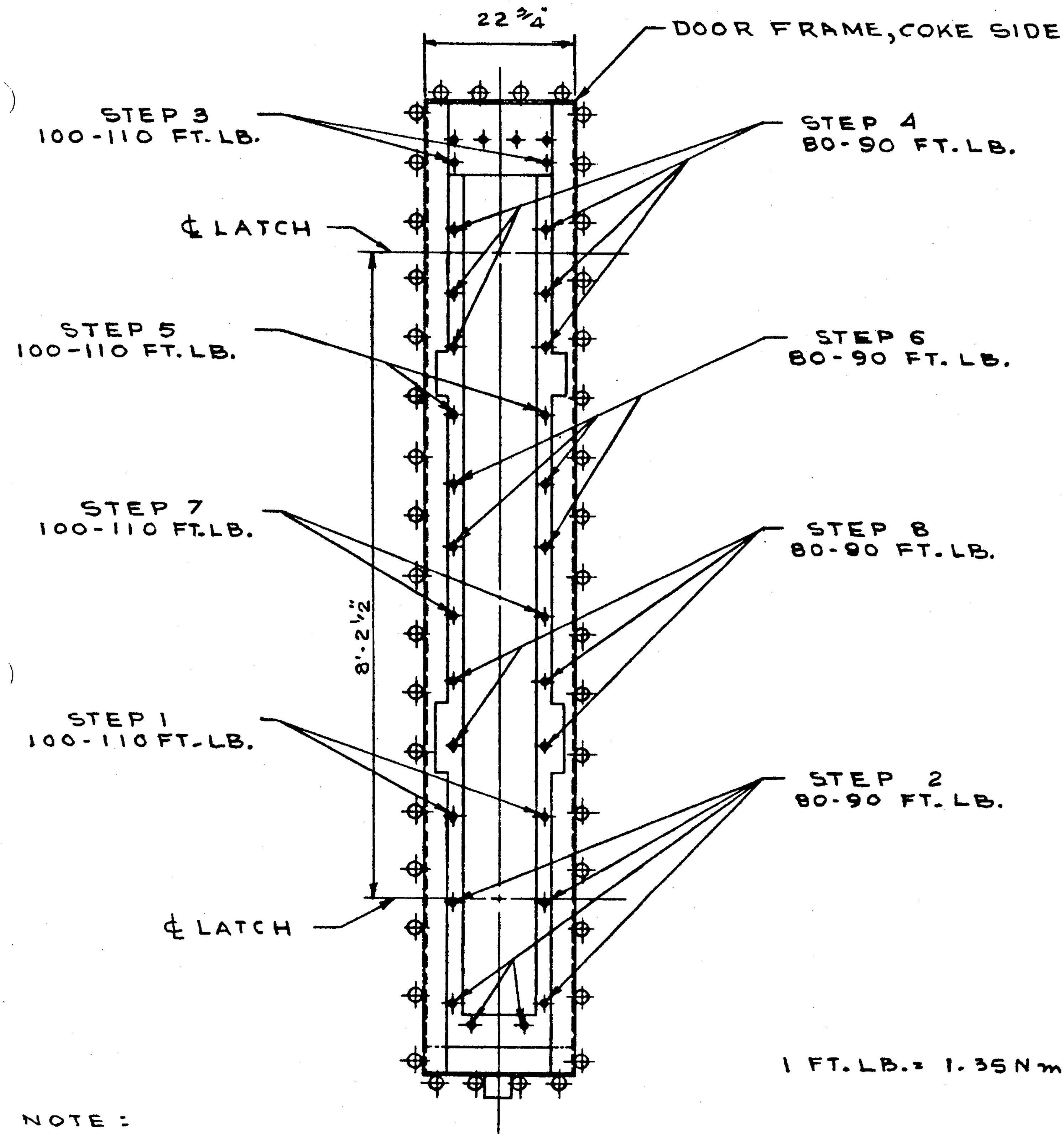


TORQUE SPECIFICATIONS ARE FOR 1"-8NC (25.4mm) ASTM A-325 BOLTS AND NUTS.

1 FT. LB. = 1.35 Nm

TITLE TORQUE SEQUENCE FOR PLUG RETAINER NUTS ON USS-2 COKE OVEN DOORS AT GENEVA WORKS – COKE SIDE (SIMILAR FOR PUSHER SIDE)

Figure 3-29-a



NOTE:
TORQUE SPECIFICATIONS ARE FOR 3/4"-10 NC ASTM A-325 BOLTS

TORQUE SEQUENCE FOR PLUG-RETAINER NUTS ON USS-1 COKE-OVEN DOORS AT CLAIRTON WORKS, BATTERIES 1-3, COKE SIDE

Figure 3-29-b

TITLE: METHOD FOR MEASURING WAVINESS OF SEAL KNIFE-EDGE SURFACE FOR USS-2 COKE-OVEN DOORS

1" = 25.4 mm

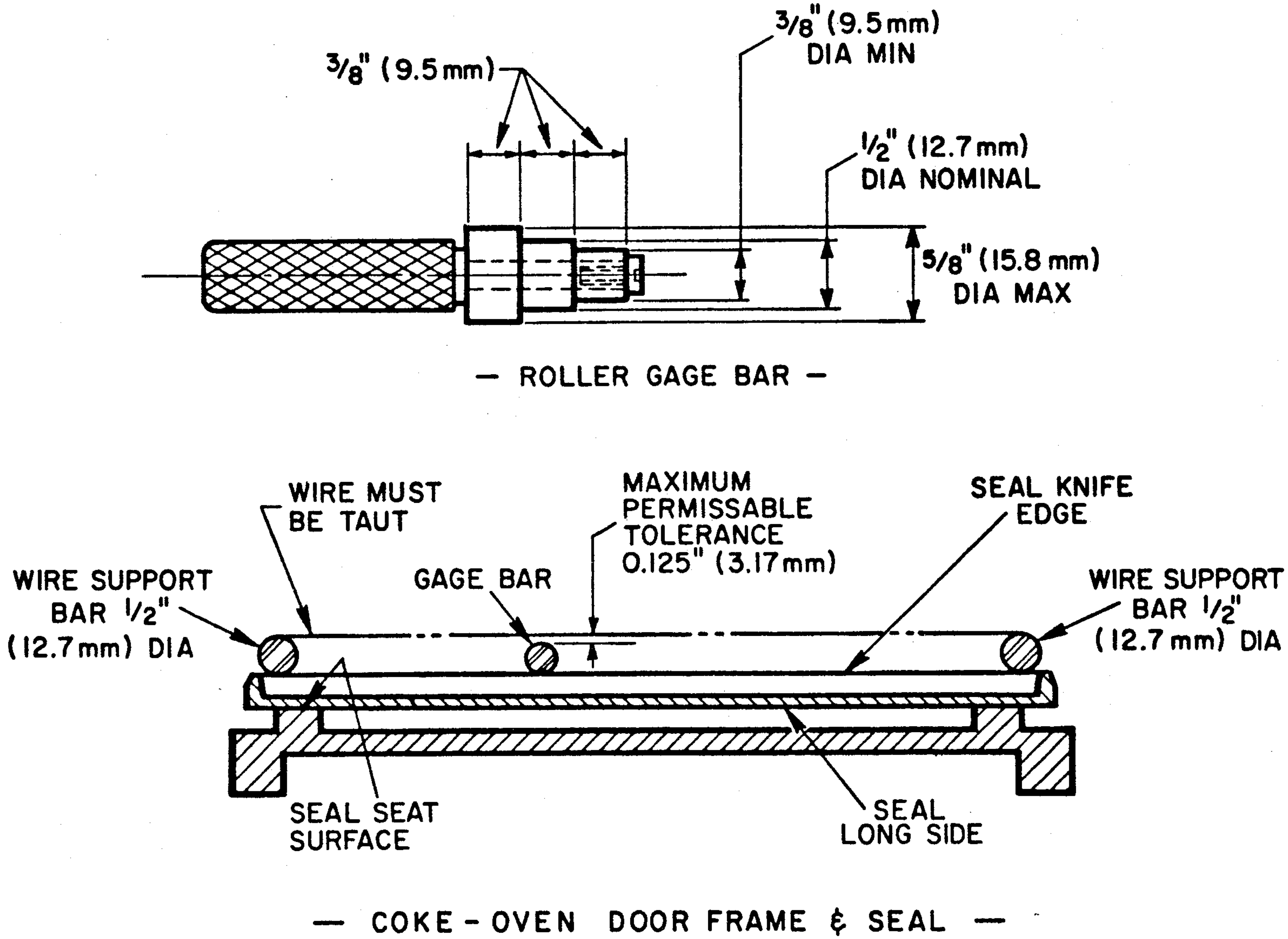
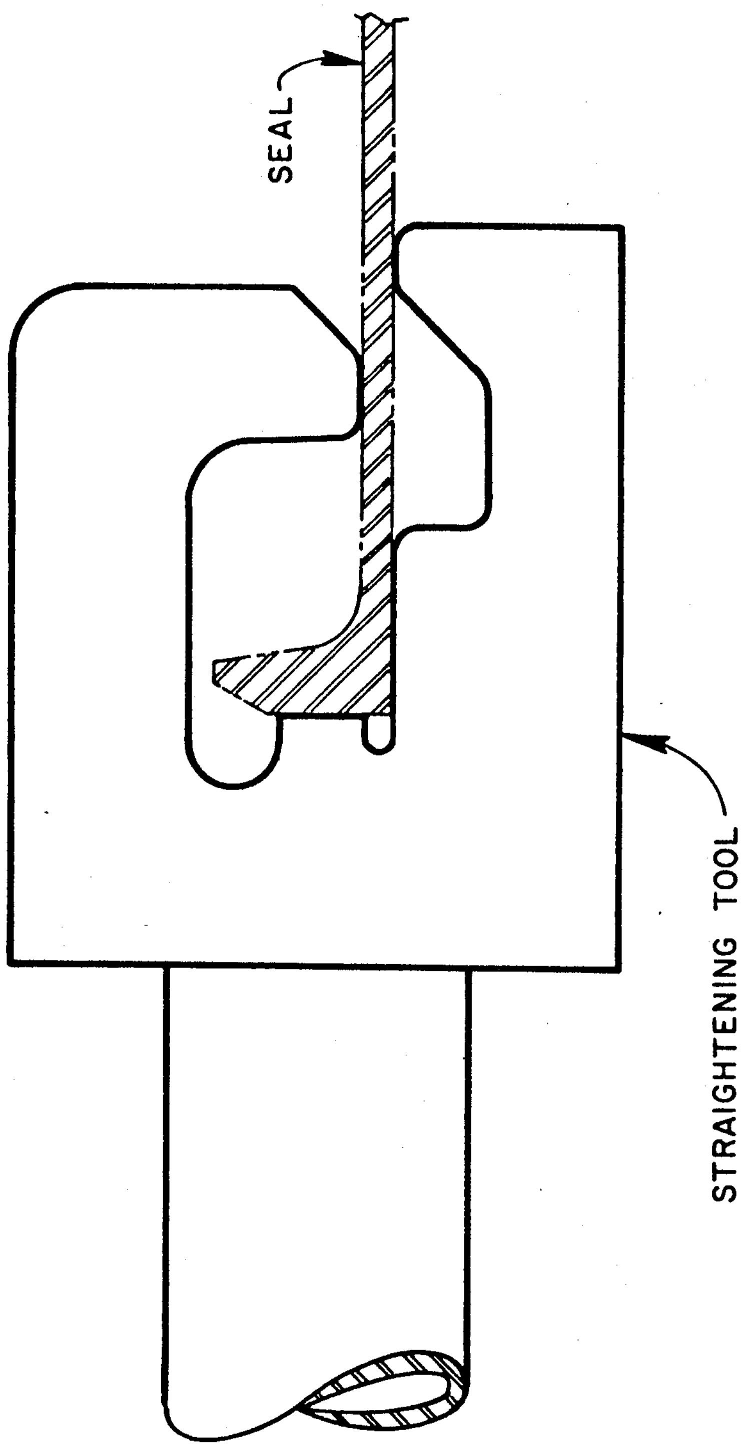
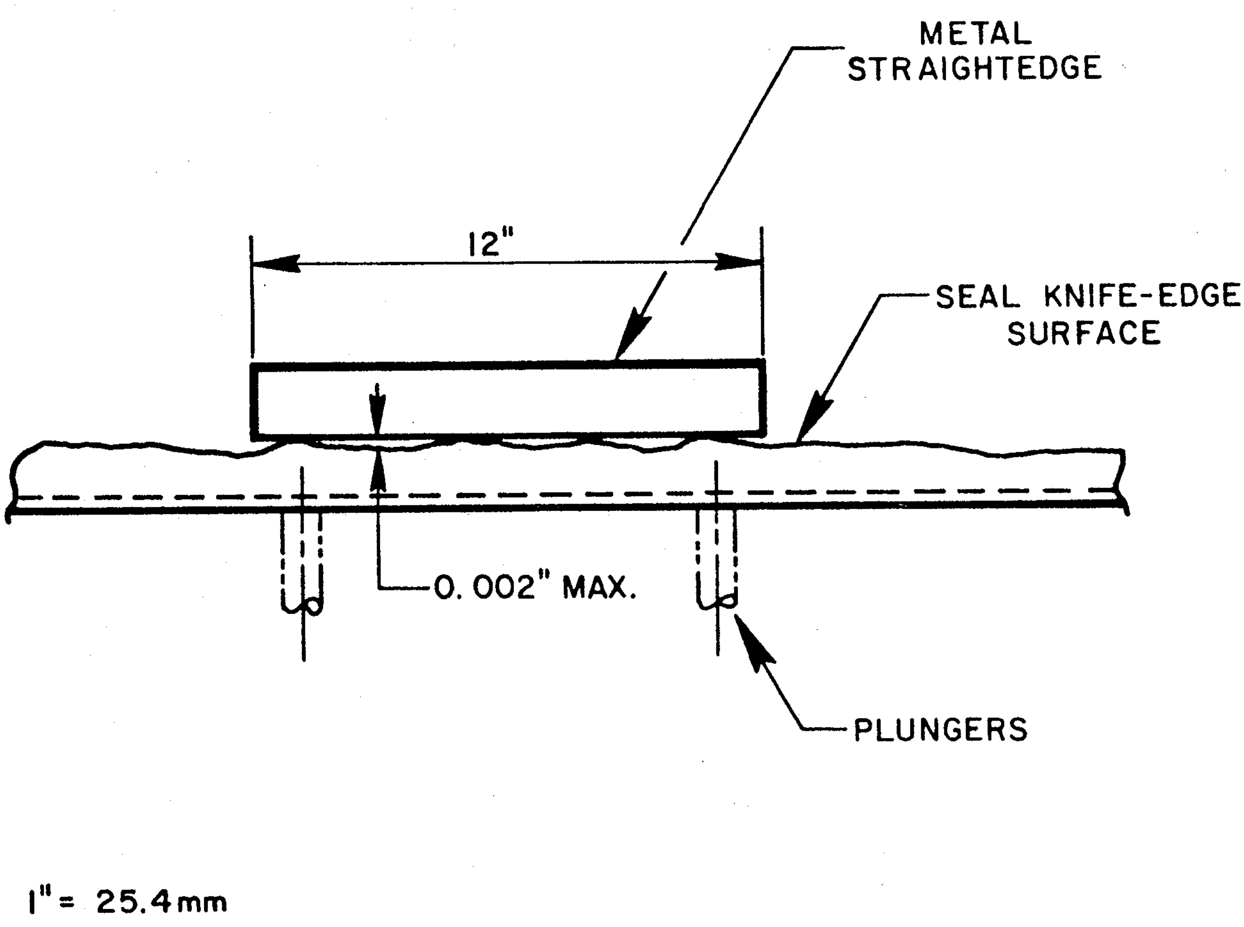


Figure 3-30



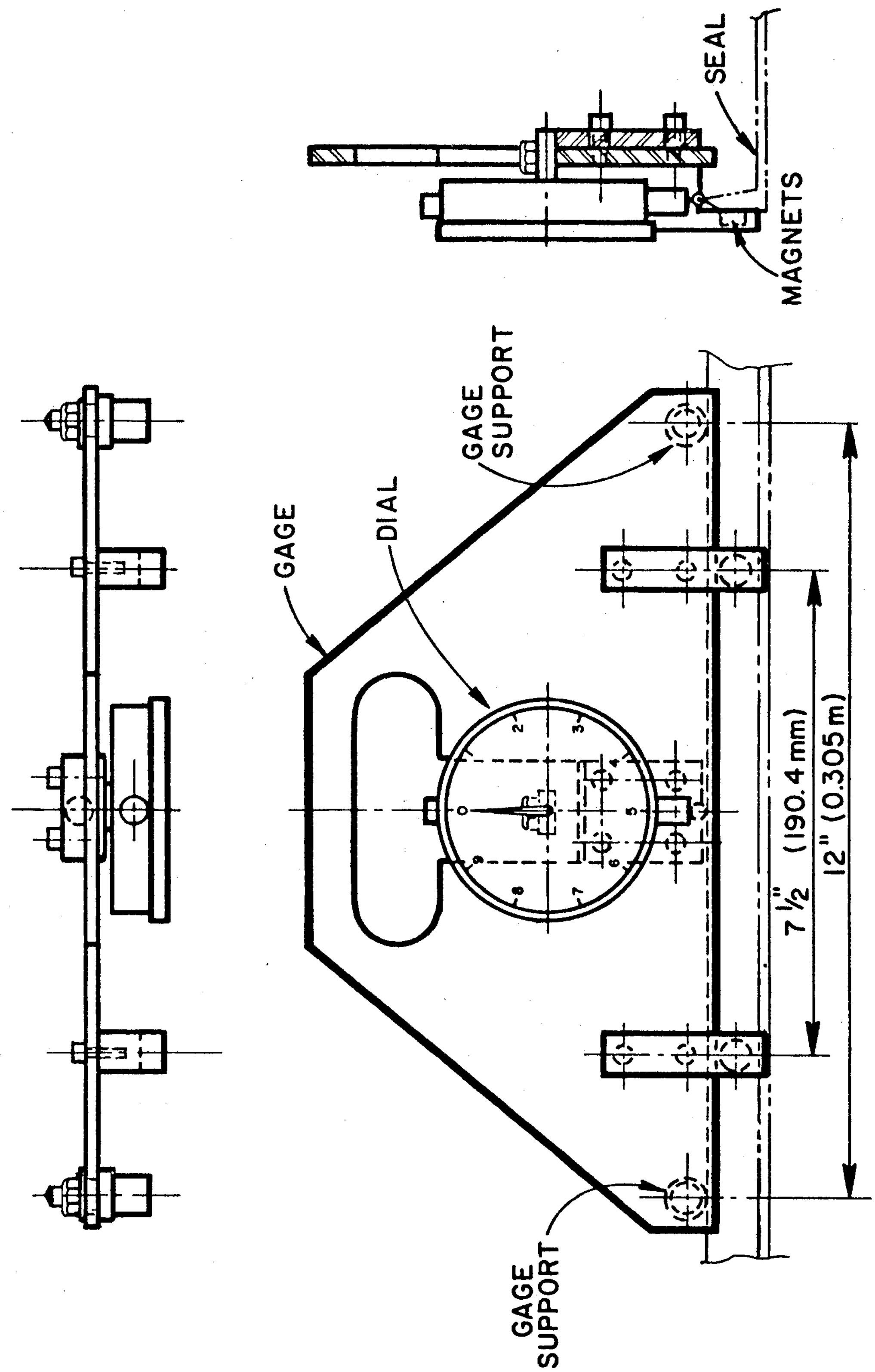
TITLE STRAIGHTENING TOOL FOR COKE OVEN DOOR SEAL

Figure 3-31



TITLE FLATNESS TOLERANCE FOR SEAL KNIFE-EDGE FOR COKE OVEN DOORS

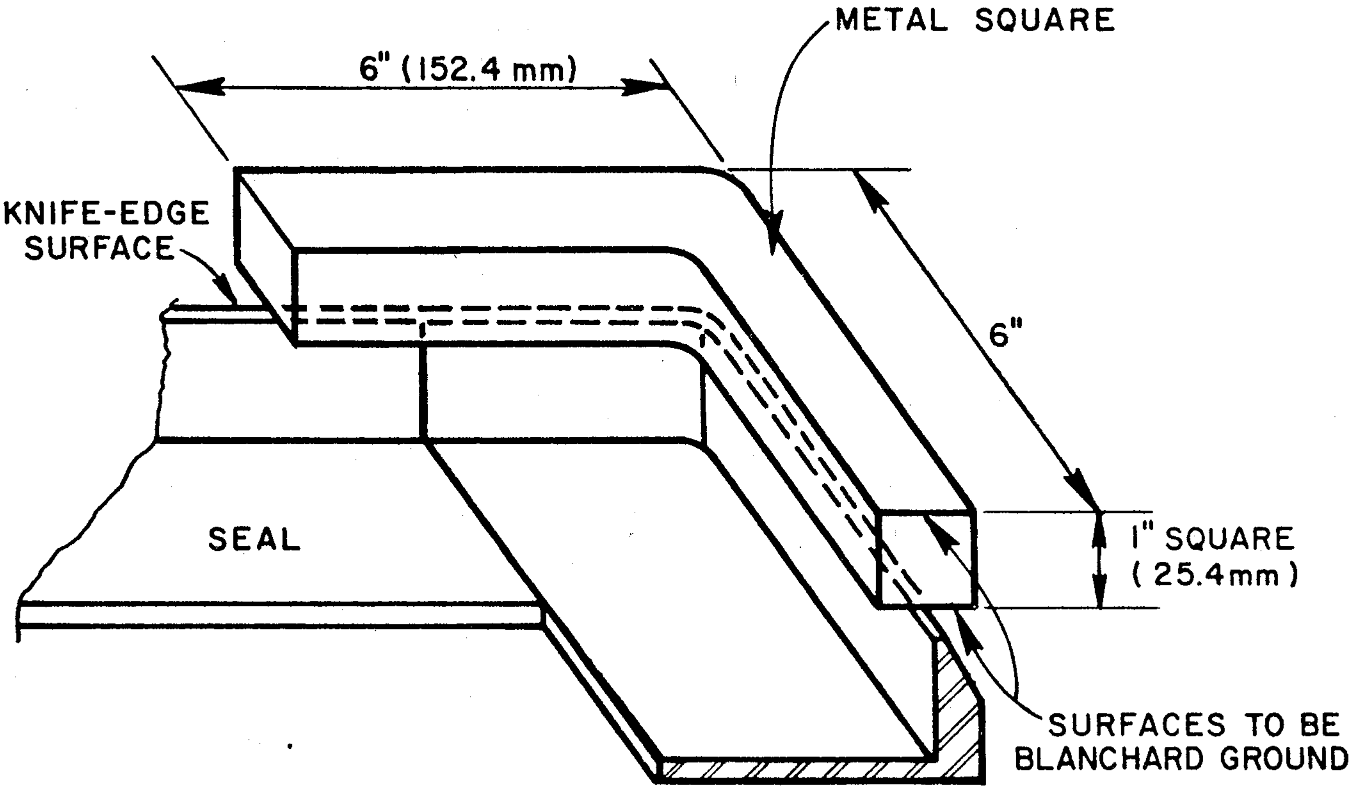
Figure 3-32



1" = 25.4mm

TITLE DIAL GAGE FOR MEASURING KNIFE-EDGE FLATNESS OF SEALS FOR COKE OVEN DOORS

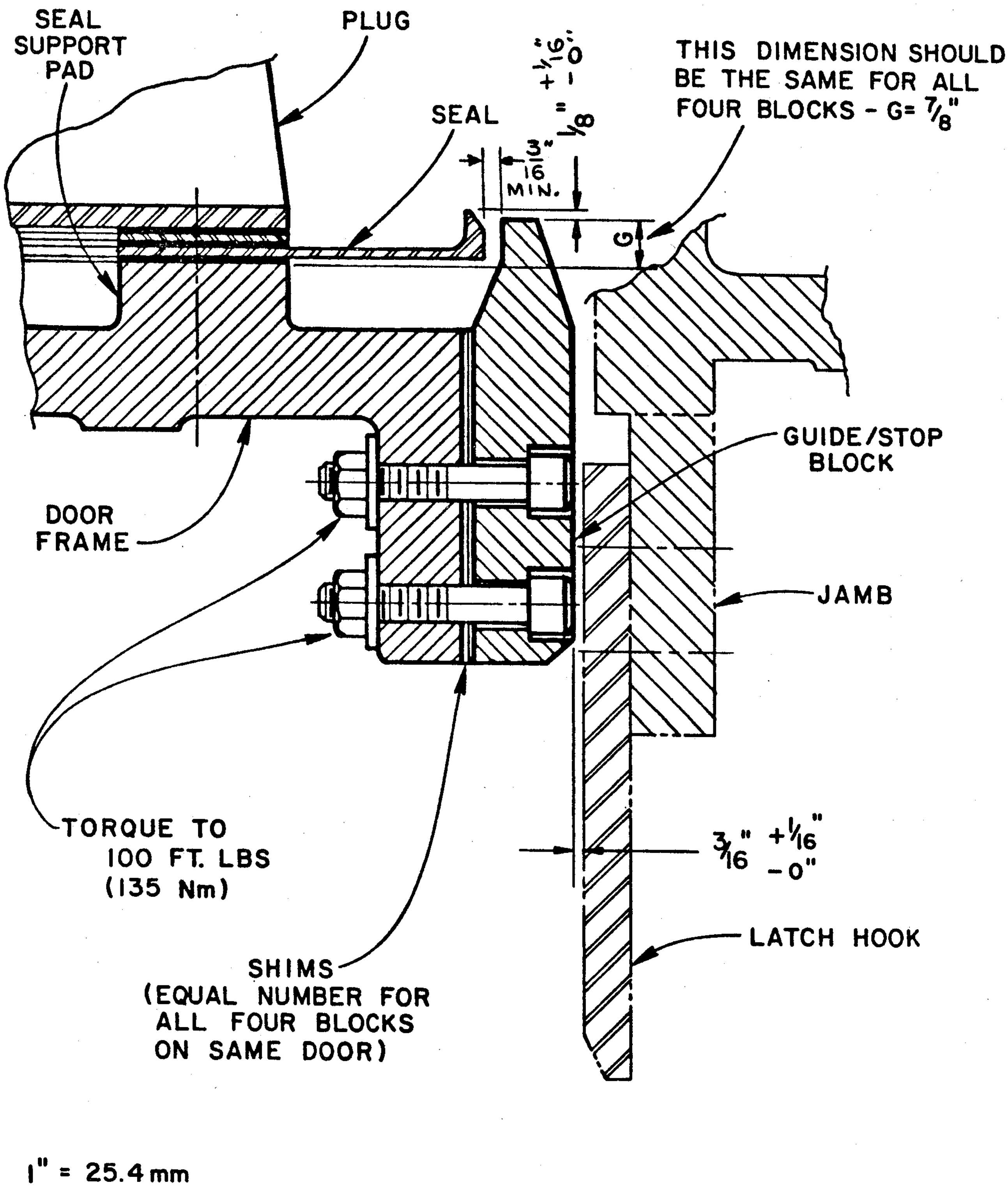
Figure 3-33



1" = 25.4 mm

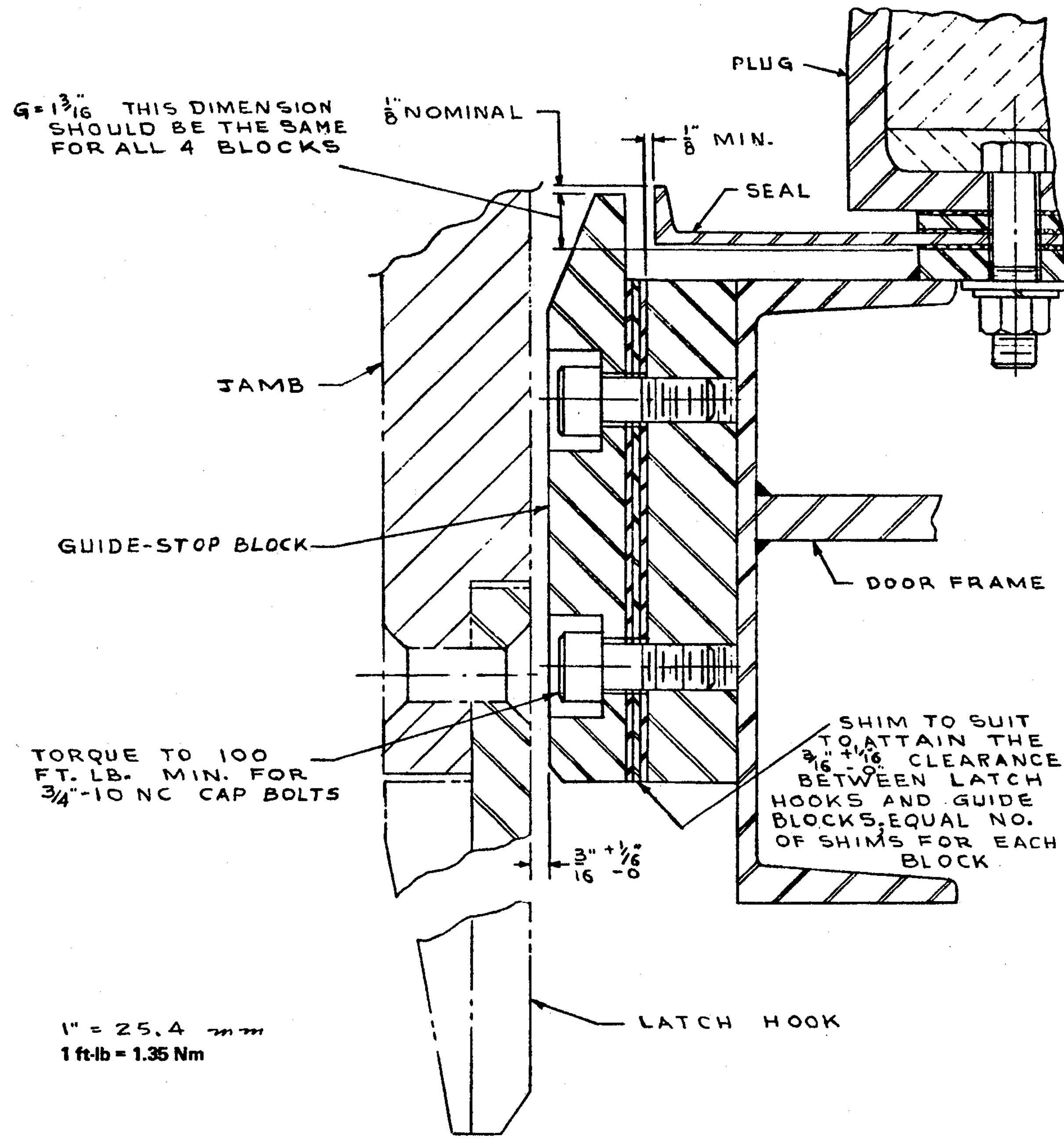
TITLE METHOD FOR CHECKING THAT KNIFE-EDGE SURFACES OF SEALS ARE IN SAME PLANE

Figure 3-34



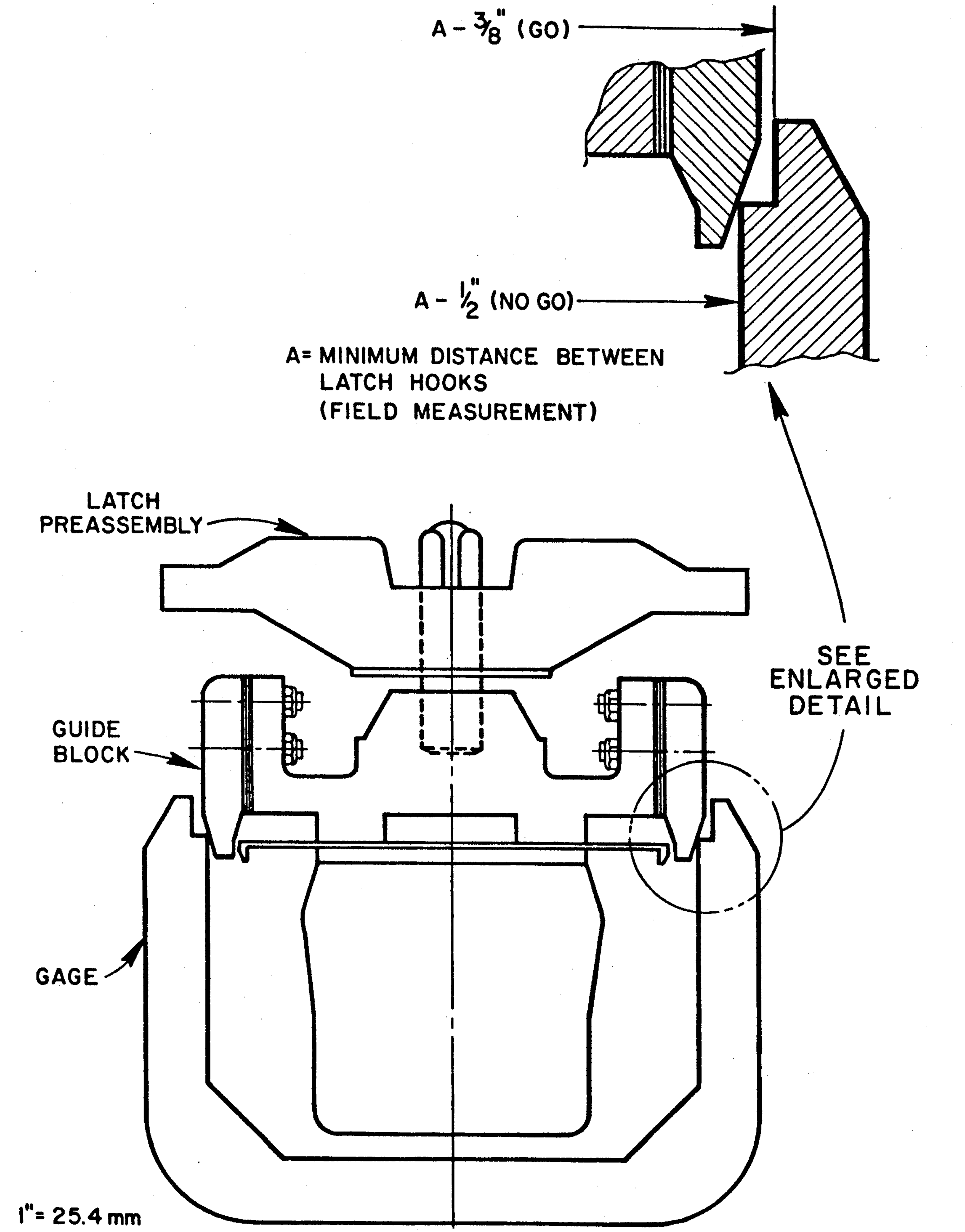
TITLE: ASSEMBLY OF GUIDE/STOP BLOCKS TO USS-2 COKE OVEN DOORS AT GENEVA WORKS

Figure 3-35-a



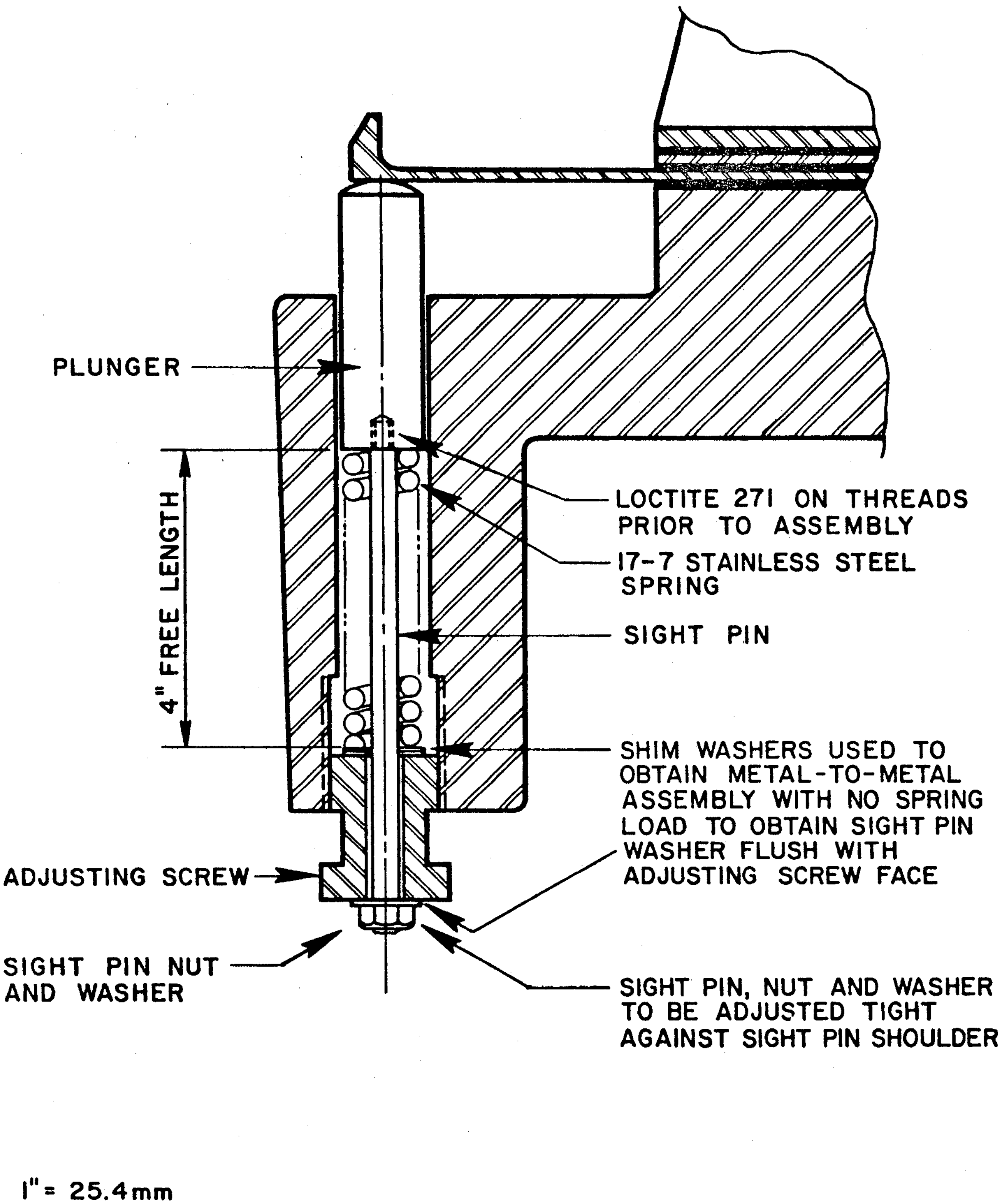
ASSEMBLY OF GUIDE/STOP BLOCKS TO USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 3-35-b



TITLE GUIDE GAGE FOR USS-2 COKE OVEN DOORS AT GENEVA WORKS

Figure 3-36



TITLE SPRING-PLUNGER MODULE ASSEMBLED TO USS-2 COKE OVEN DOORS AT GENEVA WORKS

Figure 3-37

4. DOOR INSTALLATION AND SEAL ADJUSTMENT

To ensure that the maximum sealing capability of the oven doors is realized, the doors must be properly installed and adjusted. The following procedures should be carefully followed:

4.1 DOOR INSTALLATION

4.1.1 The operating battery foreman must be present to supervise the cleaning of the jamb and oven opening.

4.1.2 All carbon, tar, and debris which would interfere with proper door placement must be removed. This includes the cleaning of (a) the jamb sealing surface, (b) the inside jamb surface, (c) the door support pads, (d) the hearth plate, (e) the sill plate, and (f) the corner carbon (fillet carbon) from the oven opening, Figure 4-1.

4.1.3 The operating battery foreman must supervise the initial placement and latching of the door on the oven.

4.1.4 For top-supported doors, the approved three-step latching procedure consists of (a) tightening both latches simultaneously, (b) tightening the top latch with full power, and (c) tightening the bottom latch with full power. See Section 5.6. For bottom-supported doors, the approved three-step latching procedure consists of (a) tightening both latches to 550 ft.-lbs. full power simultaneously, (b) tightening the bottom latch with 550 ft.-lbs. full power, and (c) tightening the top latch with 550 ft.-lbs. full power.

4.1.5 The millwright, using an 0.060-inch (1.5 mm) long-handle feeler gage, should check to determine that at least 3 of the 4 stop blocks are within 0.060 inch of the jamb sealing surface, Figure 4-2. This is the criterion used to determine whether the door is properly positioned in the oven opening.

4.1.5.1 If less than 3 stop blocks are within 0.060 inch of the jamb sealing surface, the door is removed and the foreman determines what is preventing the door from properly entering the oven opening and institutes corrective measures.

4.1.5.2 If 3 stop blocks are within 0.060-inch of the jamb sealing surface, the seal plungers can be adjusted.

4.2 SEAL ADJUSTMENT

The following steps 4.2.1 to 4.2.9 should be performed prior to the first charge of the oven.

4.2.1 Starting at the middle of the door, back out the adjusting screw until the plunger no longer exerts force on the seal (no contact).

4.2.2 Run the adjusting screw in until the plunger just contacts the seal, then tighten the adjusting screw an additonal 1/2 turn, Figure 4-3.

4.2.3 Adjust all plunger assemblies up to the top latch in this manner.

4.2.3.1 If two millwrights are adjusting the door, each side of the door can be adjusted simultaneously.

4.2.3.2 If only one millwright is adjusting the door, adjustments should be alternated from side to side, Figure 4-4-a for USS-2 doors, and Figure 4-4-b for USS-1 doors.

4.2.4 Above the top latch, back out the adjusting screw until the plunger no longer contacts the seal.

4.2.5 Run the adjusting screw in until the plunger just contacts the seal, then tighten adjusting screw 1-1/2 additional full turns.

4.2.6 Adjust all screws above the latch in this manner, alternating from side to side if only one millwright is adjusting the door.

4.2.7 Return to the middle of the door and adjust all plungers on the lower half of the door in the same manner as 4.2.1 to 4.2.6. The adjusting screws down to the lower latch will be adjusted with 1/2 turn and those below the lower latch will receive 1-1/2 full turns after the plungers are brought up to just contact the seal.

4.2.8 Using a long-handle feeler gage, check for gaps greater than 0.008 inch (0.2 mm) between the knife edge of the seal and the sealing surface of the jamb.

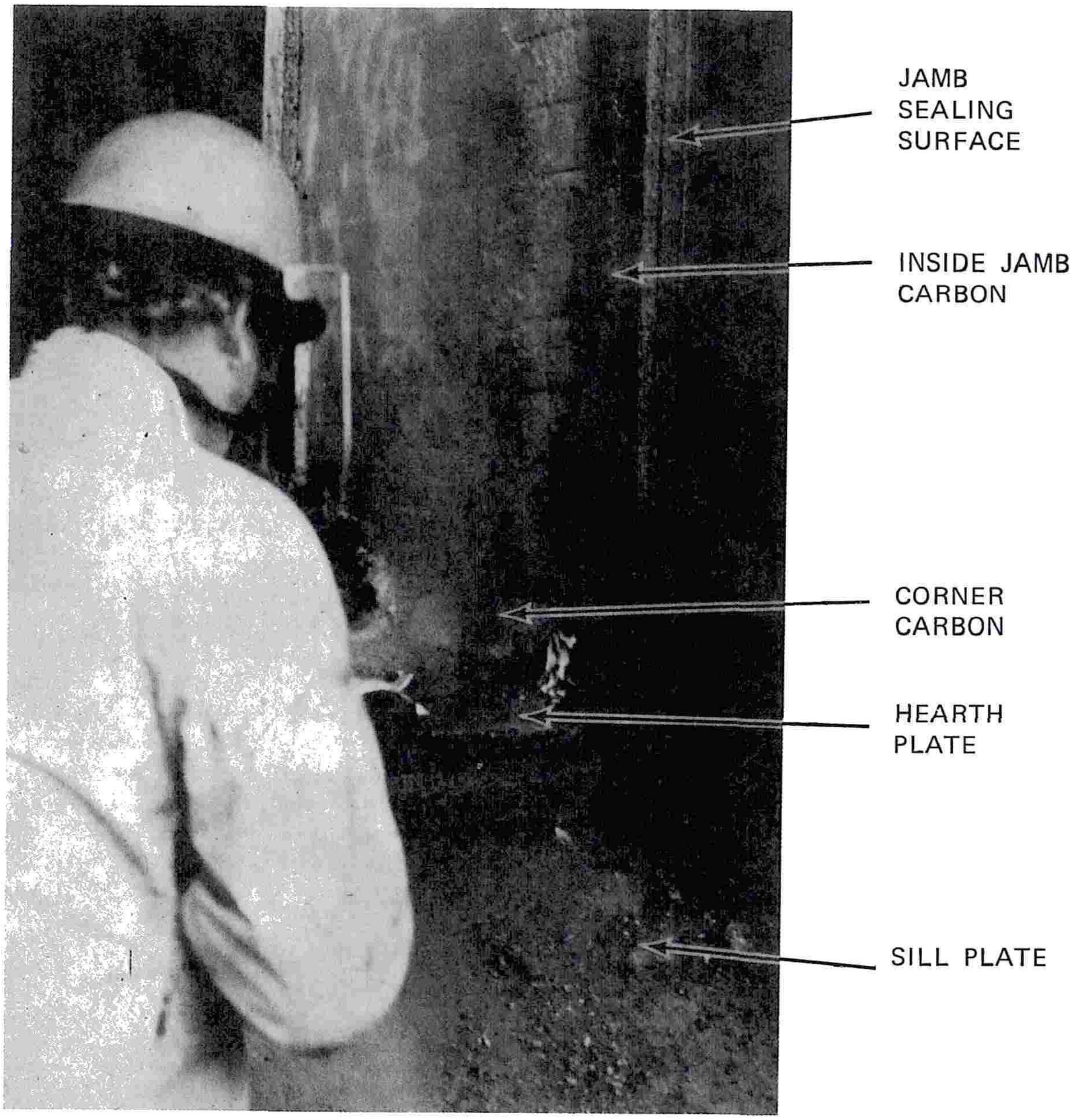
4.2.9 Close up any gaps greater than 0.008 inch by adjusting appropriate plunger screws, but do not exceed 2 additional turns on any adjusting screw.

NOTE: Steps 4.2.1 to 4.2.9 should have been done prior to the first charge. The following steps are taken after the oven is charged.

4.2.10 After the oven is charged, adjust only those plungers necessary to reduce heavy leakage. Do not exceed the 2 additional turns on any adjusting screw.

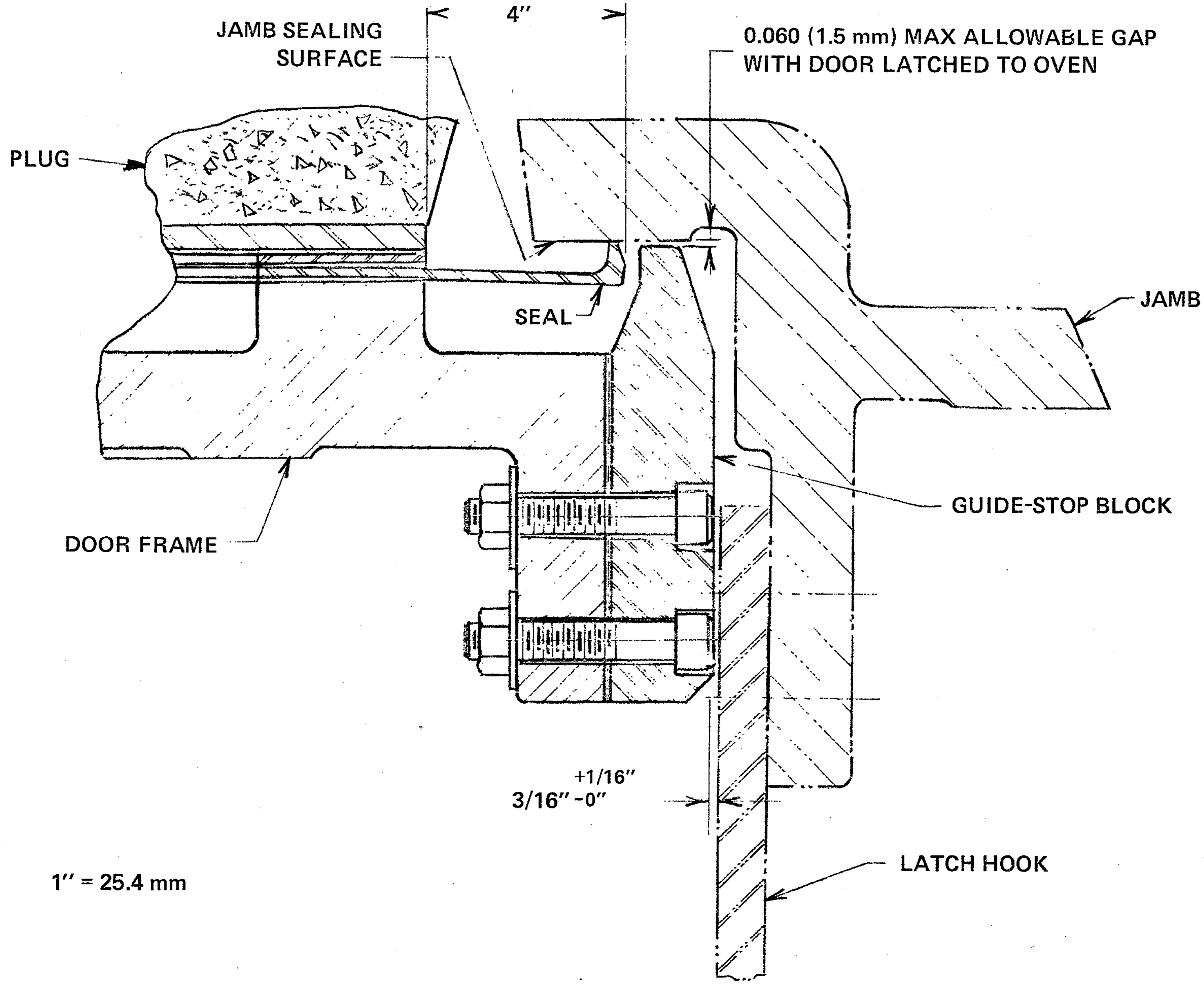
4.2.11 After the third coking cycle, the door is to be checked for leakage (immediately after charging the oven), and appropriate adjustments are to be made to eliminate any leakage. Do not exceed the 2 additional turns allowed on any adjusting screw.

4.2.12 If the coke-oven doors have been properly assembled, installed, and adjusted, satisfactory sealing should be achieved unless some irregularity exists on the jamb sealing surface. Such irregularities should be identified and the jamb should be repaired or replaced as needed.



CLEANING OF OVEN OPENING PRIOR TO DOOR INSTALLATION

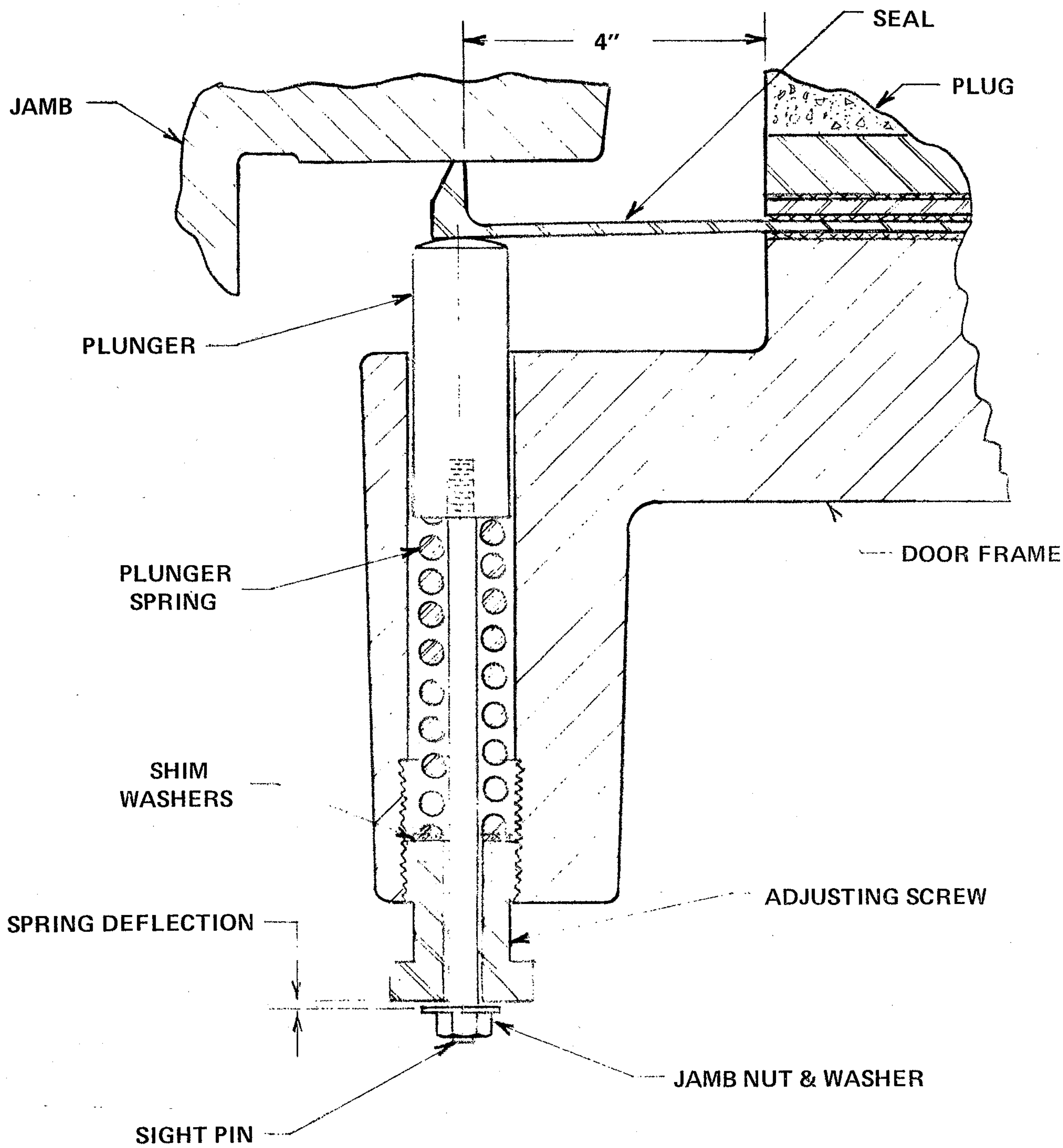
Figure 4-1



1″ = 25.4 mm

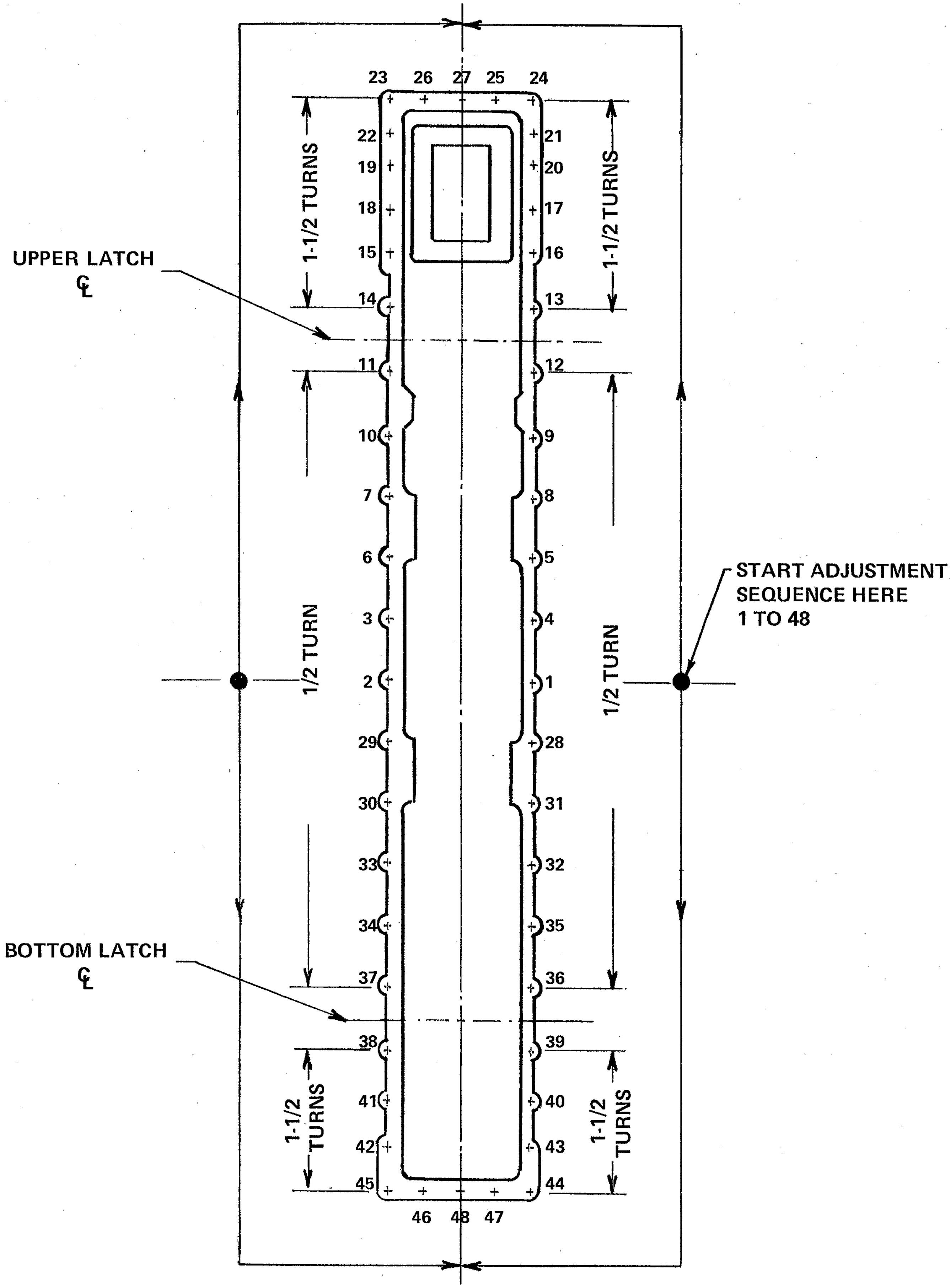
RELATIVE POSITION OF GUIDE-STOP BLOCK TO JAMB WHEN USS-2 DOOR IS LATCHED TO OVEN, GENEVA WORKS

Figure 4-2



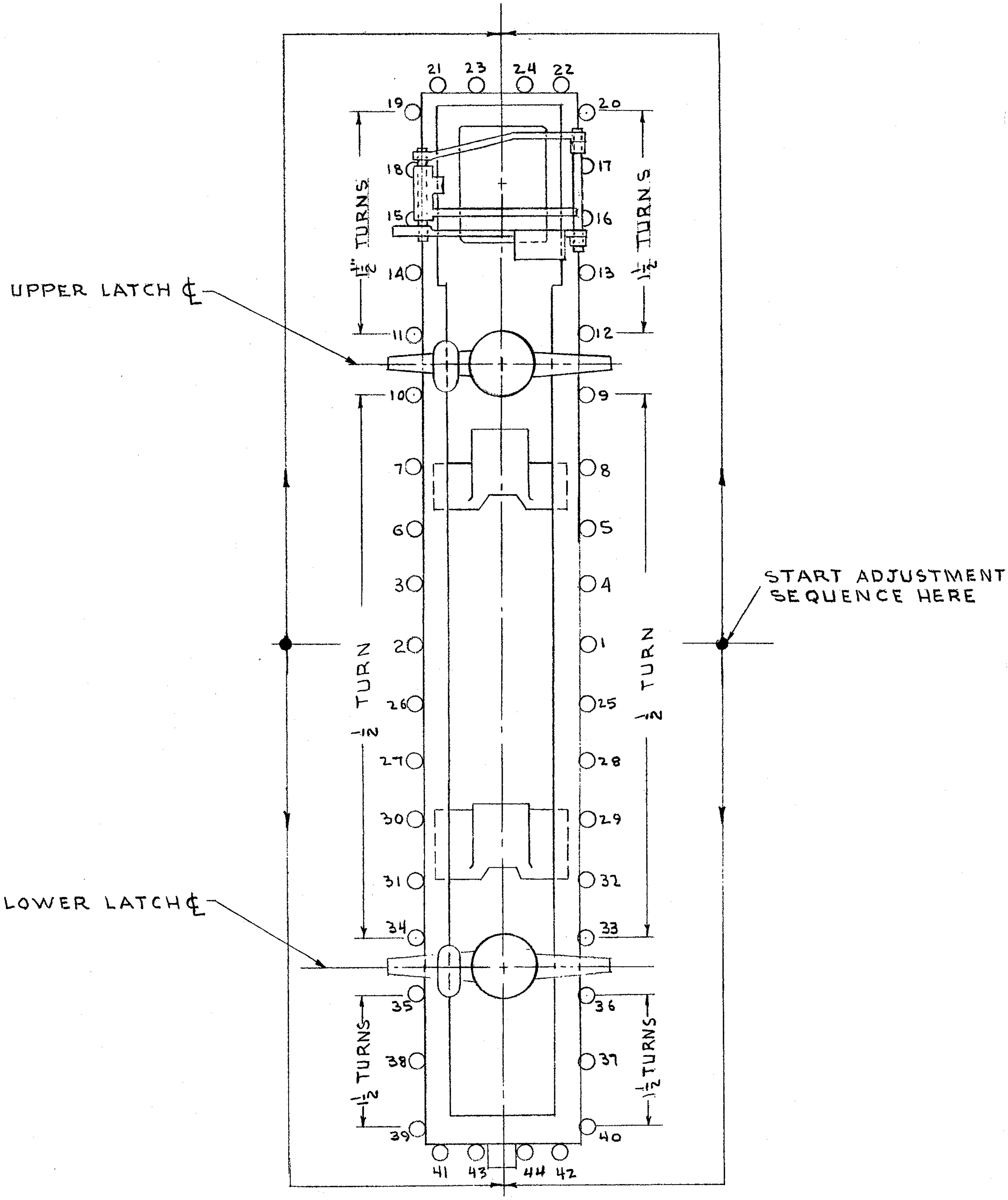
USS-2 PLUNGER ASSEMBLY INSTALLED IN DOOR FRAME WITH DOOR LATCHED TO OVEN, GENEVA WORKS

Figure 4-3



SEAL SPRING PLUNGER ADJUSTMENT SEQUENCE
FOR USS-2 COKE OVEN DOOR, GENEVA WORKS, P.S.

Figure 4-4-a



SPRING PLUNGER ADJUSTMENT SEQUENCE FOR USS-1 COKE-OVEN DOOR, CLAIRTON WORKS, BATTERIES 1-3

Figure 4-4-b

5. DOOR SPOTTING AND HANDLING

"Spotting" refers to the placement of movable machines in a specific location. Coke-battery operators must spot door-extractor machines, coke guides, larry cars, and pusher machines beside the specific oven being pushed.

Three general methods of spotting coke-oven machines will be discussed: 1) a mechanical sight, 2) a reflected-light-beam spotter, and 3) laser beams.

Handling refers to the unlatching, lifting, removal, replacement, and latching of the door with respect to the oven.

5.1 DESIGN OF MECHANICAL SIGHT

Figure 5-1 shows the recommended mechanical sight. It is mounted beside the operator on the window sill of the door machine. This sight meets the following three design requirements.

5.1.1 It must be long enough to provide front and rear reference points. Single pointers, pegs, or marks on the window sill will not do this.

5.1.2 The sight should project beyond the door machine so that it is no more than 2 to 3 inches (50 to 80 mm) from the stationary targets on the battery. However, the part which projects beyond the door machine requires a break-away attachment in case it strikes a bent buckstay or some other obstruction.

5.1.3 The sight should be adjustable. (See Section 5-3 for adjustment procedure.)

5.2 DESIGN OF REFLECTED-LIGHT SIGHT

The reflected-light sight provides the operator with an image on the windshield of the cab. The operator then spots the pusher machine so that the reflected image appears to be in front of the stationary target on the battery. Regardless of where the operator stands, the light image appears at the correct position on the windshield.

Figure 5-2 shows the location and operation of the reflected-light-beam spotter. The following two design features are important.

5.2.1 The reflecting-glass plate is half-way between the light source and the stationary target. Most pusher machines are designed to accommodate this requirement by arranging the front windshield half-way between the light source and the target. Where this has not been done, a separate glass plate must be mounted outside of the operator's cab. A spotting error will result when the windshield is not half-way between the light source and target, Figure 5-3.

5.2.2 The windshield panes must be parallel to each other. Otherwise, the target will appear to shift abruptly when the operator's line-of-sight crosses a strut between two window panes, Figure 5-4. This can cause a large spotting error. The glass installer should check visually to make sure the target does not appear to shift.

5.2.3 The light source must be bright, distinctive, sharply defined, and adjustable. Usually a combination red, vertical-slot, and white-round light source works best. The red slot is useful at night when many unwanted white lights will reflect from the windshield. The white spot, being brighter, will show up on sunny days when the red slot is difficult to see.

5.3 DESIGN AND CALIBRATION OF STATIONARY TARGETS

The tolerances for door spotting are becoming more stringent because of tighter clearances between the door and jamb and lower emission standards. Therefore target locations must be placed more accurately today than they were in the past. The practice of using one edge of the buckstay or the center of the buckstay provides an accuracy of ± 1.5 inches (38 mm) on typical batteries. However spotting accuracy requirements are now ± 0.25 inch (6.4 mm). Therefore, it is necessary to measure target positions on each buckstay. The recommended procedure is to use the sight on the door machines for finding the target locations.

5.3.1 When the door machine is carefully jogged into position (the easiest way to tell is when the lifting hook is centered in the lifting lug), mark the buckstay where the line-of-sight intercepts the buckstay. It is also suggested that the location of each target should be measured and recorded. Target locations should be remeasured on both sides of an oven that has been left open for a prolonged period (for example when the coke is stuck).

5.3.2 After the target position has been found, marked, and recorded, the stationary target may be installed. The recommended target is a Hilti stud with a bright yellow circle painted around it.

5.3.3 On the pusher side, the targets should be positioned using the reflected light in the operator's cab.

5.4 CALIBRATION OF SIGHTS ON SPARE MACHINES

It is important to follow a calibration procedure for the sights that will allow all the machines on adjacent batteries to be used interchangeably.

5.4.1 The first sight may be installed at any position. The only precaution is that its aim must fall on all buckstays. All other door or pusher machines that operate on the same track must be brought to the same oven used for locating the sight on the first machine. If this is not done, the spare machine will not be able to use the same targets set up for the regular machine.

5.5 DESIGN OF LASER SPOTTING

The newest spotting method in use by U. S. Steel was developed for No. 2 battery at Fairfield Works. It consists of a laser-beam generator gun mounted on the moving machine which produces an orange beam. The beam produces an orange spot on the coke battery. Operators can watch the orange spot move along the battery and stop the machine when the spot is in the correct position. Sometimes targets for the orange spot are needed and sometimes a nut, hole, or corner on the oven doors topside plugs will serve as targets.

Laser spotters must be designed so that operating personnel cannot look into the beam generator gun. Mount the beam generator gun so that the entire beam is above the heads of personnel on pusher machines. Laser beams do not have scattered light. Looking at the orange spot is not harmful; but being hit in the eye by the beam may be.

5.6 CALIBRATION OF TORQUE DRIVE AND LATCH SCREWS

Coke-oven doors must be squeezed against the door jambs. The squeezing should be sufficient to cause a uniform force of 100 pounds per lineal inch (17 N/mm) of door seal. The squeezing force is obtained by jacking the doors toward the jambs with latch screws.

5.6.1 The torque drives for the latch screws require periodic calibration. Somewhere along the track serving all the interchangeable door-extractor machines a torque-drive calibration station should be established. A torque-drive calibration station consists of the heads of two latch screws connected by a linkage to hydraulic pistons, Figure 5-5. Machine operators may calibrate the torque-drive system by engaging the snouts of the torque drive into the two latch-screw heads in the same way that the latch screws on a door are engaged. During the calibration it is important that the snouts are axially aligned with the heads of the latch screws. Pressure developed in the piston when torque is applied measures the torque output of the torque drive. The required torque (pressure reading) depends on the size of the coke-oven doors. For USS-2 doors, the pressure-torque relationship and required torque are shown in Figure 5-6-a. For USS-1 doors, the pressure-torque relationship and required torque are shown in Figure 5-6-b.

5.7 DOOR REPLACEMENT

Seal damage usually occurs during door replacement. Door replacement may also damage door support lugs, latch hooks, and brickwork. Damage is caused by forcing an incorrectly spotted door into the oven when the travel brakes are locked. The guide blocks can help to wedge the door into position for small spotting misalignment, but unseen damage may result, especially to the brickwork behind the jamb if the misalignment is large (greater than ±1/4 inch or 6.4 mm) and the door is forced into the oven opening. Following is the recommended procedure for door replacement.

5.7.1 Spot the extractor.

5.7.2 Lock the travel brakes.

5.7.3 Start the forward motion of the extractor.

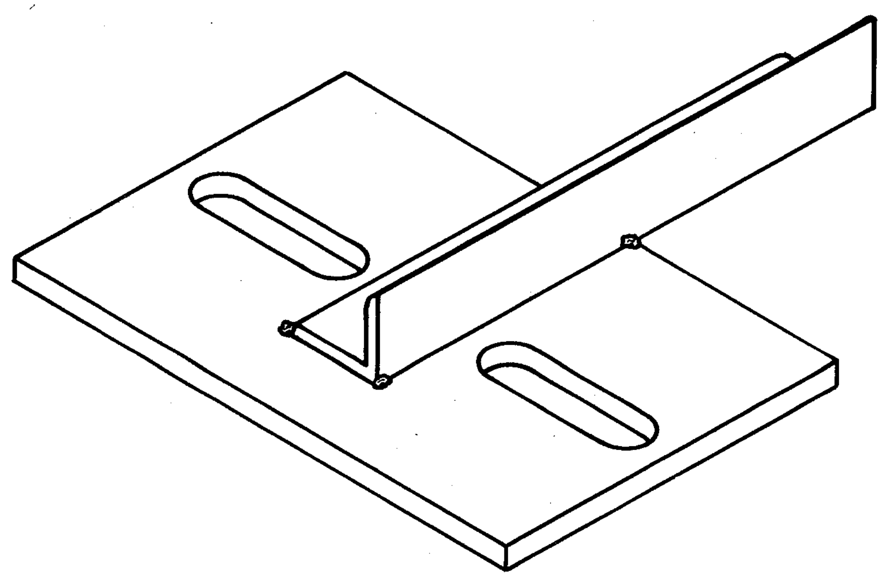
5.7.4 Stop the extractor forward motion as the guide blocks are about to enter between the latch hooks.

5.7.5 Check for spotting error.

5.7.6 If the spotting error is greater than ±0.25 inch (6.4 mm), withdraw door from oven and repeat steps 5.6.1 to 5.6.5.

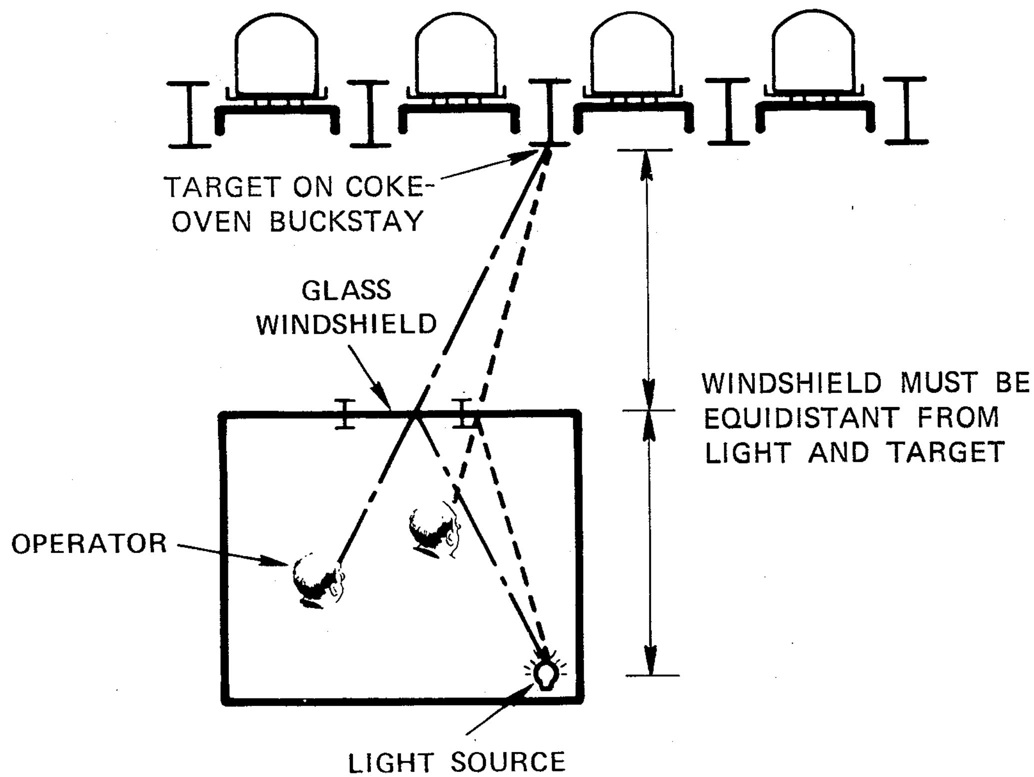
5.7.7 If the spotting error is less than ±0.25 inch, (6.4 mm) (slight or no interference of the guide blocks with the latch hooks), release the travel brakes.

5.7.8 Resume the forward motion of the extractor.



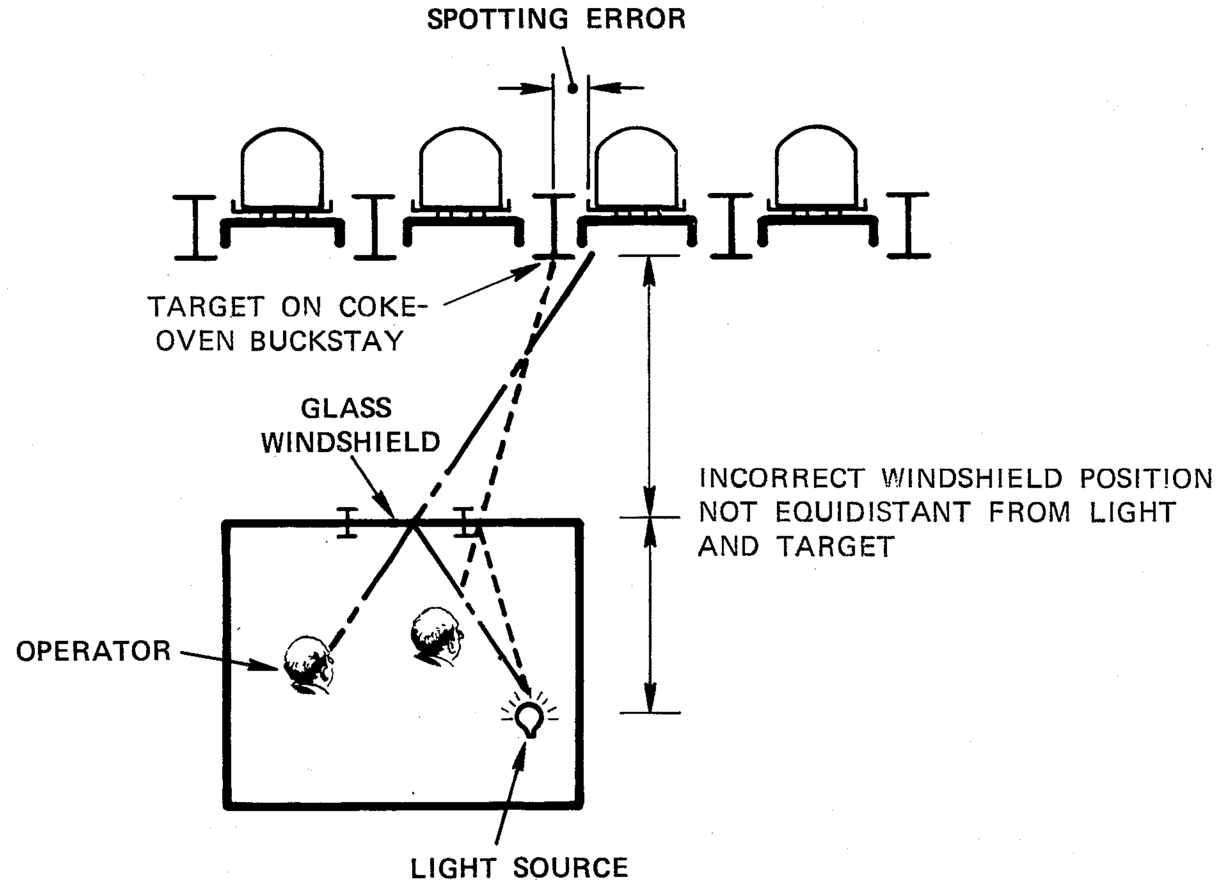
MECHANICAL SIGHT FOR COKE-OVEN-DOOR
EXTRACTOR MACHINE

Figure 5-1



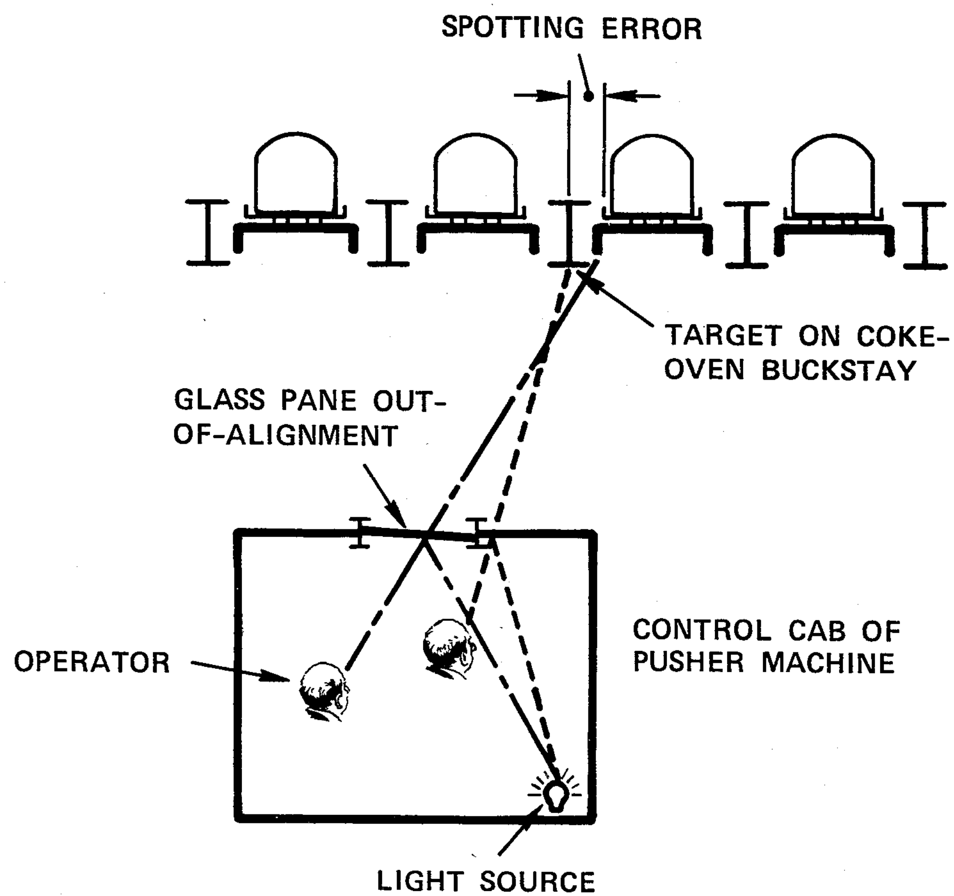
PLAN OF REFLECTED-LIGHT-BEAM SPOTTER ON COKE-OVEN PUSHER MACHINES SHOWING AUTOMATIC CORRECTION FOR OPERATOR MOVEMENT

Figure 5-2



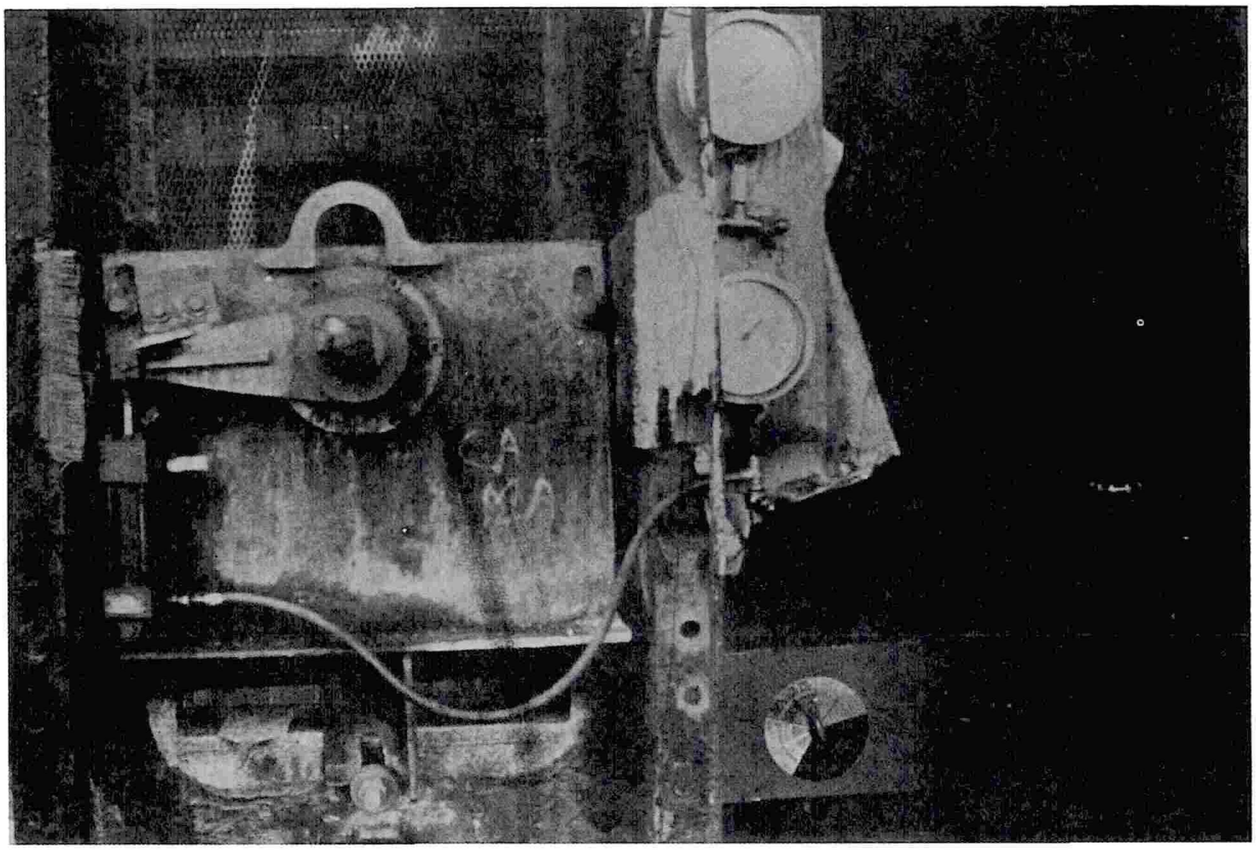
PLAN OF REFLECTED-LIGHT-BEAM SPOTTER ON COKE-OVEN PUSHER MACHINE
SHOWING ERROR CAUSED BY INCORRECT LIGHT-SOURCE LOCATION

Figure 5-3



PLAN OF REFLECTED-LIGHT-BEAM SPOTTER ON COKE-OVEN PUSHER MACHINE
SHOWING ERROR CAUSED BY MISALIGNED WINDSHIELD PANE

Figure 5-4



COKE-OVEN-DOOR LATCHING TORQUE CALIBRATOR

Figure 5-5

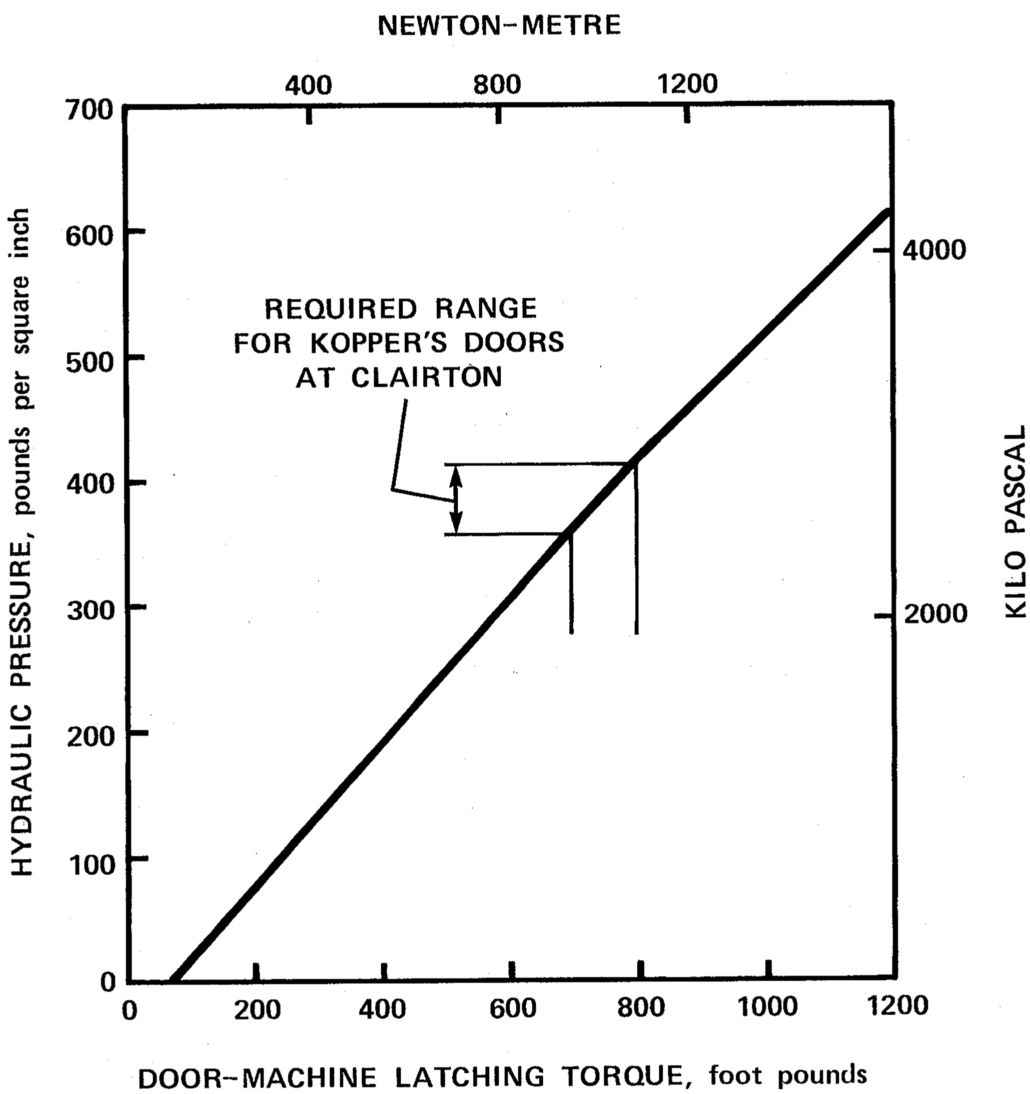


CHART FOR CONVERTING PRESSURE READING TO TORQUE AT COKE-OVEN-DOOR LATCH-TIGHTENING CALIBRATION STATION

Figure 5-6-a

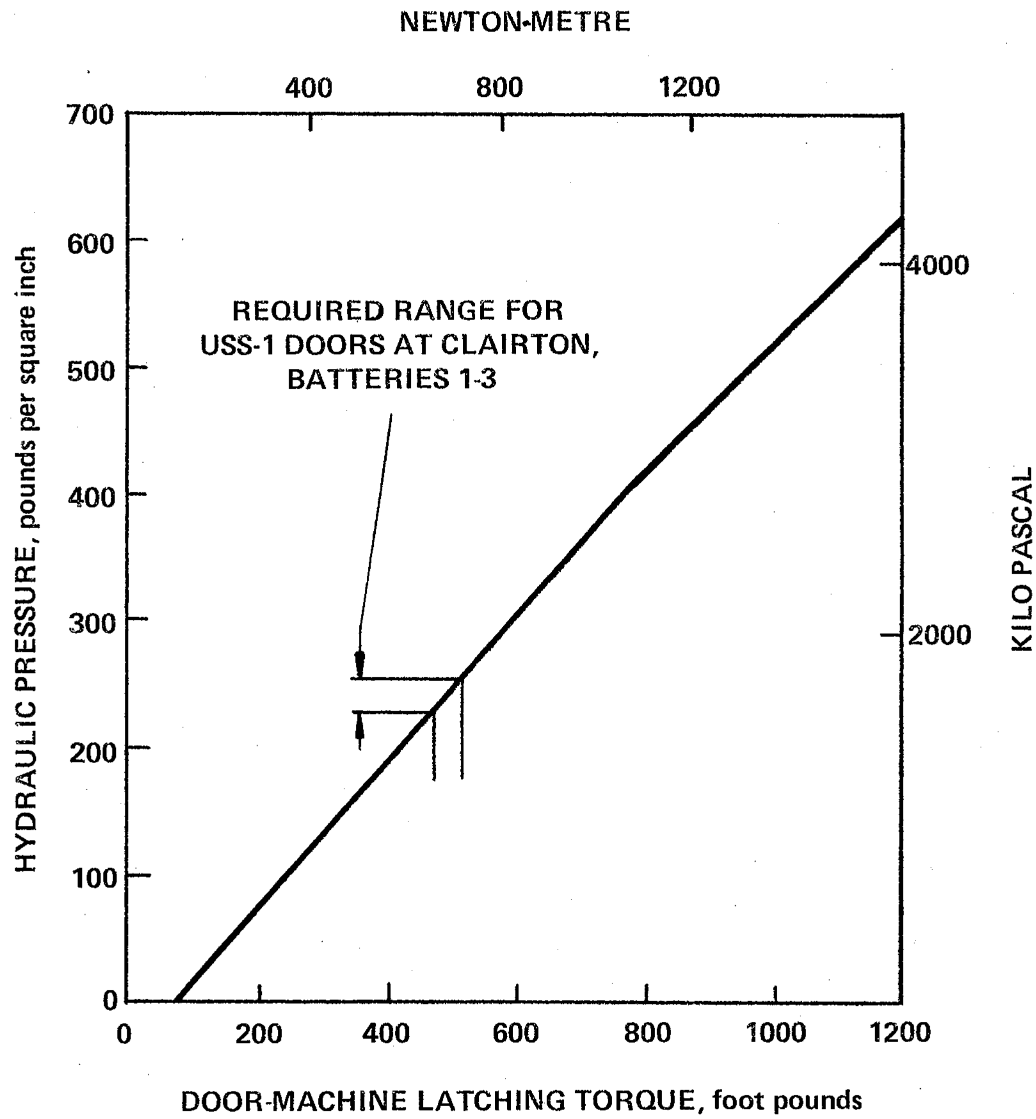


CHART FOR CONVERTING PRESSURE READING TO TORQUE AT
COKE-OVEN-DOOR LATCH-TIGHTENING CALIBRATION STATION

Figure 5-6-b

6. DOOR AND JAMB CLEANING

In minimizing visible coke-oven-door emissions, door- and jamb-cleaning procedures must be implemented to ensure that accumulated tar, carbon, or other debris does not interfere with the proper placement of the door into the oven. Formation of carbonaceous material can make it impossible to properly adjust the door seals during initial door installations, and during the coking cycles can prevent the intimate contact between the sealing edge and sealing surface necessary to minimize emissions. Cleaning procedures will be discussed as they pertain to:

1) Initial installations of new or rebuilt doors,

2) Normal operation after every cycle,

3) Troubleshooting doors that exhibit excessive leakage (leakage greater than 45 minutes).

NOTE: All these cleaning procedures are to be performed only with the use of hand-operated cleaning tools unless specifically stated otherwise. Pneumatic air tools or any other power-driven devices should not be used except when removing corner carbon (fillet carbon) from the oven floor/wall intersection. Electric or pneumatic-powered tools have been known to cause knicks in the door-sealing edges and jamb sealing surfaces, resulting in unnecessary leakage problems, and have also caused serious damage to door plugs.

6.1 CLEANING OPERATIONS PRIOR TO NEW/REBUILT DOOR INSTALLATIONS

Assuming the doors have been assembled or reconditioned in accordance with the specifications set forth in the assembly guidelines in Section 3, the following jamb and oven cleaning procedure should be adhered to prior to installing the door.

The operating battery foreman or other designated plant personnel must be present to supervise the cleaning of the jamb and oven opening.

6.1.1 Scrape clean the entire jamb-sealing surface of all tar, carbon, patching material, or other debris (see Figure 6-1). This includes both the left and right sides of the jamb running vertically from the top to the bottom of the oven opening and the horizontal sections of the sealing surface across the top and bottom of the jamb.

6.1.2 Remove all tar, carbon, or other debris from the inside jamb surface located along the perimeter of the oven opening between the jamb sealing surface and oven nosebrick (brick that butts against the jamb), Figure 6-1.

6.1.3 Clean and remove all carbonaceous material from the sill plate (if so equipped) located at the base of the jamb, Figure 6-1.

6.1.4 Scrape clean the hearth plate (metal plate lying at the base of the oven) and remove all tar, carbon, unpushed coke, or other debris.

6.1.5 The operating battery foreman, or other delegated plant personnel, is to inspect the oven proper, especially for corner carbon (fillet carbon) from the floor/wall intersection (to a depth greater than the depth of the plug), and for excessive buildup of patching material on the oven walls, Figure 6-1.

6.1.6 A metal template is used to check for corner carbon, Figure 6-2. Insert the template in along the oven floor and at numerous oven heights up to 6 inches from the oven floor. If the template touches the jamb sealing surface as shown in Figure 6-2, there should not be any interference problem with door placement due to corner carbon. If the template does not contact the jamb sealing surface, corner carbon may keep the door from entering far enough into the oven for good sealing. This interference must be eliminated before installing the door.

6.1.7 Corner carbon is very hard and cannot be removed with hand-operated cleaning tools. Pneumatic air hammers, chisel hammers, or jack hammers will be needed to break up this corner carbon. Recheck for interference by using the template as discussed in 6.1.6.

6.1.8 Inspect the door support (hanger) pads attached to the jamb webs (rib) and located near the top latch hooks and remove all dirt and debris that has accumulated.

6.1.9 Upon completion of the aforementioned procedures, the operating battery foreman can proceed with installing the new or rebuilt door.

6.2 CLEANING AFTER EVERY CYCLE

Upon completion of the coking cycle, the oven doors are removed and the oven is pushed. Before replacing the doors, routine cleaning operations must be undertaken to minimize visible smoke emissions due to accumulated tar, carbon, or other debris on the oven door seal or jamb. The door machine operators or specifically assigned door and jamb cutters are responsible for seeing that these procedures are performed properly.

6.2.1 The door-machine operator or door cleaner is responsible after every cycle for cleaning and removing all tar and carbon deposits from the gas channel, accumulated deposits along the sealing knife edge, the plug sections, and retainers.

6.2.2 Scrape the tar and carbon from the gas channel that runs along the perimeter of the door. The gas channel includes the section on the left and right side of the door running vertically from the top to the bottom of the door, and the horizontal section across the top and bottom of the door.

6.2.3 Remove all carbonaceous material from the door plug and plug retainer sides (if applicable).

6.2.4 Remove only accumulated deposits of tar or carbon from the sealing knife edge of the door and leveler door (pusher-side doors).

CAUTION: Avoid hitting the knife edges of the seal of both the oven door and leveler door with the manual cleaning tool. Air-powered cleaning tools can cause excessive damage to the sealing knife edges and door plug, and are therefore not to be used for routine door and jamb cleaning.

6.2.5 Scrape all tar and carbon deposits from leveler door seat (pusher-side doors). Also remove any deposits from the hot face of the leveler door, Figure 6-3.

6.2.6 The jamb cutter is responsible after every cycle for cleaning and removing the tar, carbon, or other debris from the jamb sealing surface, sill plate, and hearth plate. Inside jamb carbon should be removed whenever it prevents proper door placement.

6.2.7 Scrape the entire jamb sealing surface of all tar, carbon, patching material, or other debris, Figure 6-1. This includes both the left and right sides of the jamb running vertically from the top to the bottom of the oven opening, and the horizontal sections across the top and bottom of the jamb.

6.2.8 Clean and remove all carbonaceous material from the sill plate (if so equipped) located at the base of the jamb, Figure 6-1.

6.2.9 Scrape all tar, carbon, unpushed coke, or other debris from the hearth plate (metal plate lying at the base of the oven) for a distance greater than the depth of the plug.

6.2.10 Remove all tar, carbon, or other debris from the inside jamb surface that could interfere with door placement. The inside jamb surface is located along the perimeter of the oven opening between the jamb sealing surface and oven nosebrick (brick that butts against the jamb), Figure 6-1.

6.2.11 Upon completion of these aforementioned procedures, the door can be installed and latched properly on the oven.

6.3 CLEANING PROCEDURES AS RELATED TO TROUBLESHOOTING

In an attempt to keep door leakage to a minimum, the following cleaning procedures should be used in conjunction with the guidelines for troubleshooting, Section 7. The door-machine operator, pusherman, battery foreman, or any other authorized personnel will report any door that leaks excessively (longer than 45 minutes after the charge) to a designated supervisor. The battery foreman who is on duty the next time the leaking door is removed will plan and personally supervise special cleaning of the door, jamb, inside jamb, hearth plate, door support pads and oven opening. (If more appropriate, this responsibility could be delegated to other plant personnel such as maintenance or environmental health.)

6.3.1 Scrape all tar and carbon from the gas-channel that runs along the perimeter of the door.

6.3.2 Remove all carbonaceous material from the door plug and plug retainer sides (if applicable).

6.3.3 Remove only the accumulated deposits of tar or carbon from the sealing knife edge of the door and leveler door (pusher-side doors).

CAUTION: Avoid hitting the knife edge of the seals of the pusher and coke side oven doors and the leveler door with the manual cleaning tool. Air-powered cleaning tools can cause excessive damage to the sealing knife edges and door plug, and are therefore not to be used for door and jamb cleaning.

6.3.4 Scrape all tar and carbon deposits from the leveler door seat (pusher-side door only). Also remove any deposits from the hot face of the leveler door.

6.3.5 Scrape the entire jamb-sealing surface of all tar, carbon, patching material, or other debris, Figure 6-1.

6.3.6 Remove all tar, carbon, or other debris from the inside jamb surface located along the perimeter of the oven opening between the jamb sealing surface and the oven nosebrick, Figure 6-1.

6.3.7 Clean and remove all carbonaceous material from the sill plate (if so equipped) located at the base of the jamb, Figure 6-1.

6.3.8 Scrape all tar, carbon, unpushed coke, or other debris from the hearth plate.

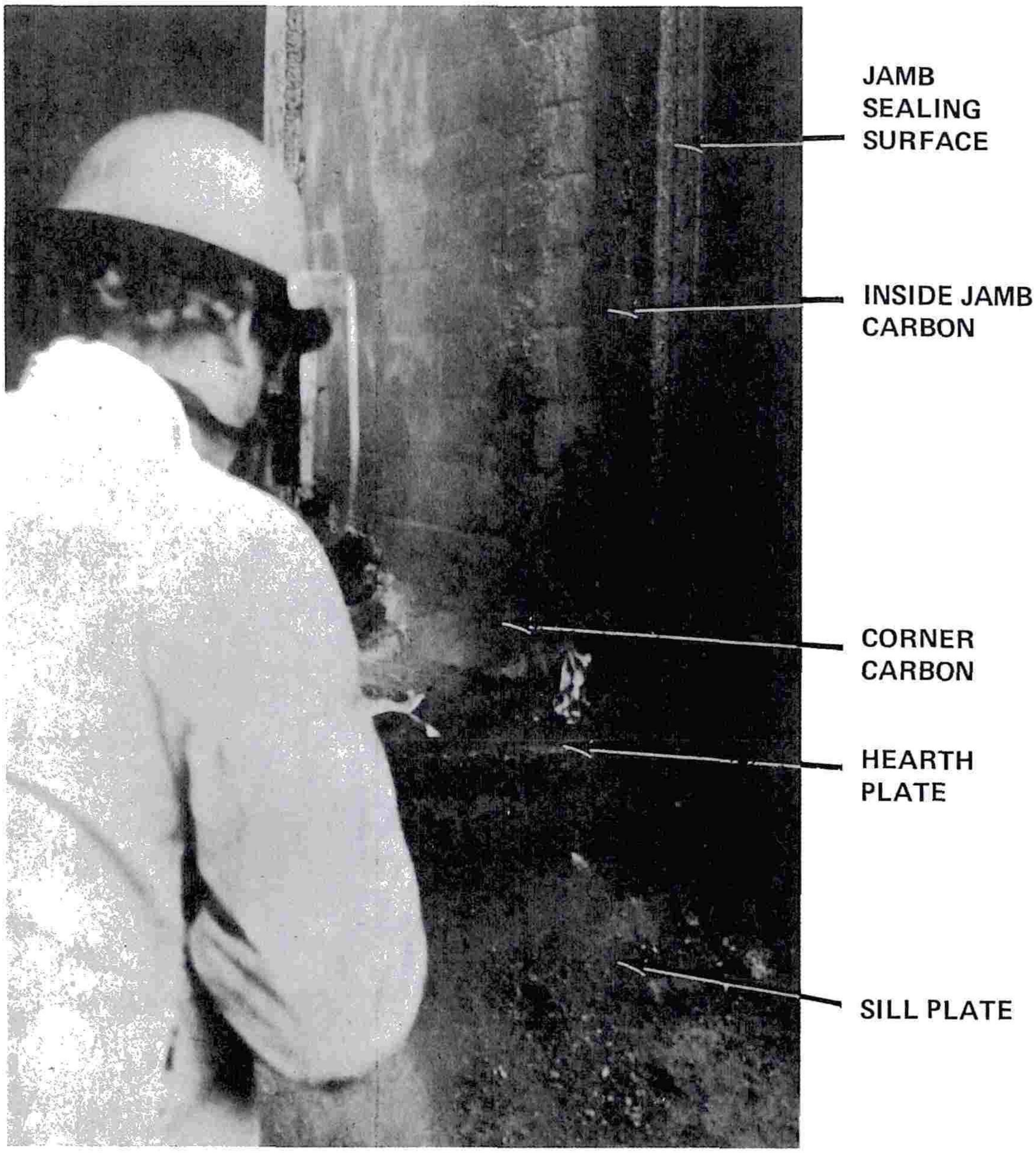
6.3.9 The operating battery foreman, or other delegated plant personnel, is to inspect the oven proper for corner carbon (fillet carbon) at the floor/wall intersection (to a depth greater than the depth of the plug) and for excessive buildup of patching material on the oven walls, Figure 6-1.

6.3.10 A metal template is used to check for corner carbon, Figure 6-2. Insert the template in along the oven floor and at numerous oven heights up to 6 inches from the oven floor. If the template touches the jamb sealing surface as shown in Figure 6-2, there should not be any interference problem with door placement due to corner carbon. If the template does not contact the jamb sealing surface, corner carbon may keep the door from entering far enough into the oven. This interference must be eliminated before installing the door.

6.3.11 Corner carbon is very hard and cannot be removed with hand-operated cleaning tools. Pneumatic air hammers, chisel hammers or even jack hammers will be needed to break up this corner carbon. Recheck for interference using the template as discussed in 6.3.10.

6.3.12 Inspect the door support (hanger) pads attached to the jamb webs (rib) and located near the top latch hooks. Remove all dirt and debris that has accumulated.

6.3.13 Upon completion of the aforementioned procedures, the operating battery foreman can proceed with installing the door.

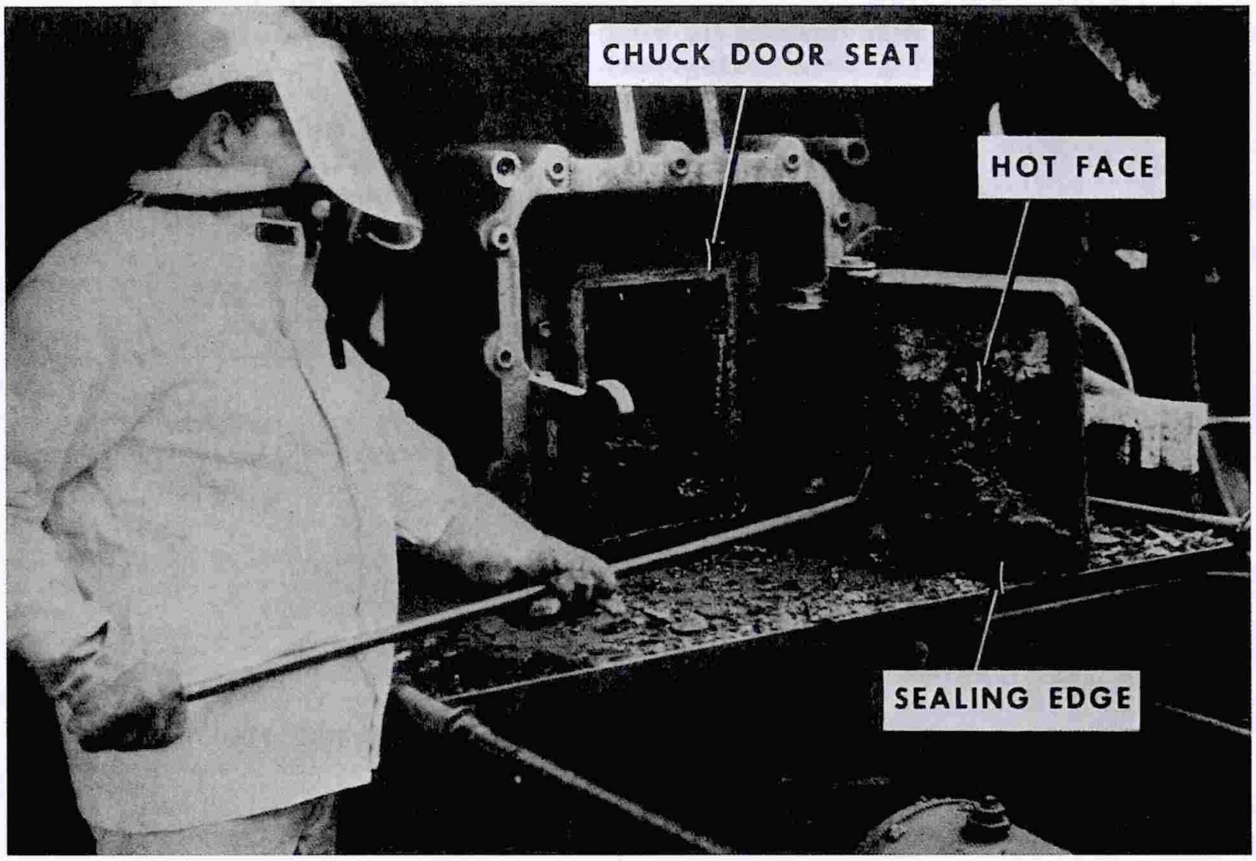


CLEANING OF OVEN OPENING PRIOR TO DOOR INSTALLATION

Figure 6-1

CHECKING OVEN COVER (FILLET)
CARBON WITH TEMPLATE

Figure 6-2



LEVELER DOOR (CHUCK DOOR) CLEANING
AFTER EVERY CYCLE

Figure 6-3

7. TROUBLESHOOTING

Experience has shown that doors may seal satisfactorily for several weeks, then for no apparent reason begin to leak. If the cause of the leakage is not immediately identified and corrective measures taken, the sealing performance will steadily worsen, and the probability of the occurence of door fires will increase. In an attempt to keep door leakage to a minimum, the following guidelines for troubleshooting door leakage should be employed.

7.1 The door-machine operator, pusherman, battery foreman, or any other authorized personnel will report any door which leaks excessively (longer than 45 minutes after the charge) to a designated supervisor.

7.2 The battery foreman who is on duty the next time the leaking door is removed will supervise special cleaning of the door, jamb, inside jamb, hearth plate, and oven opening.

NOTE: If more appropriate, this responsibility could be delegated to other plant personnel such as maintenance or environmental health.

7.3 The battery foreman will inspect the door to determine whether there has been any visible damage done to any of the door components that would prevent the door from providing satisfactory sealing.

7.3.1 If the door has been damaged, it is replaced with a new or reconditioned door.

7.3.2 If there is no apparent damage to the door, it is put back on the oven after the paper cleaning has been completed. See previous Section 6.3 on door and jamb cleaning.

NOTE: Often the door leakage stops after thorough door and jamb cleaning.

7.4 If the door leaks after the oven is charged, the battery foreman will notify the millwrights to make the necessary seal adjustments.

7.5 The millwright, using an 0.060-inch long-handle feeler gage, will check to see that at least 3 of the 4 stop blocks are within 0.060 inch of the jamb sealing surface.

NOTE: This is the criterion used to determine whether the door is properly positioned in the oven opening.

7.5.1 If the door is not properly positioned in the oven the millwright will notify the battery foreman.

7.5.1.1 The battery foreman will inspect the door and oven opening the next time the door is removed for pushing to determine why the door would not properly enter the oven opening.

7.5.1.2 Once the problem has been identified, the foreman will institute corrective measures before the door is replaced on the oven.

7.5.2 When the door is properly positioned in the oven, the millwrights will adjust only those plungers necessary to stop the leakage, being careful not to overadjust any individual plungers.

7.6 The door should be inspected for leakage immediately after charging the oven on subsequent charges.

7.6.1 If the door consistently leaks longer than 45 minutes after the charge, the door should be removed and replaced with a new or reconditioned door.

7.6.2 If the new or reconditioned door does not perform satisfactorily once it has been installed and adjusted properly, the jamb should be inspected for damage and repaired or replaced as needed.

7.7 If several doors on a battery begin to leak for no apparent reason, the battery foreman should check the door extractor and latching mechanisms on either the pusher or door machine to make sure the required torque for proper latching is being applied to the doors.

8. SEAL RECONDITIONING

The basic coke-oven-door structure has an expected life in excess of 20 years and is periodically rebuilt or reconditioned on a cycle of about 3 months to 3 years depending on the extent of the repairs being made. Rebuilding usually involves replacing the seal, refractory plug, damaged plunger springs, and any other damaged parts, as well as a complete lubrication and adjustment of springs. Doors are usually rebuilt at central door-repair shops that serve all coke batteries in a plant. Reconditioning involves the more frequent minor repairs that are made in smaller shops located near the batteries. These repairs are made when a door leak cannot be stopped by adjusting the plungers while the door is on the oven, but a new plug is not needed. The most frequent minor repairs are to straighten or repair a damaged door seal and to readjust the plungers.

Door-seal repair is important in the prevention of leaks from the oven. Experience in U. S. Steel's coke plants has shown that gaps between the seal and jamb can be no greater than 0.008 inch (0.20 mm) to control door emissions to zero leakage in short enough time after the coal is charged into the oven. Prior to repairing the seal the appropriate guidelines in previous Sections 3.1 to 3.4 should be followed.

8.1 CLEANING SEALS BEFORE REPAIR

Before starting the repairs, tar and hard carbon deposits are removed from the surfaces of the seal. A wooden-handled tool with a hardened-steel blade is suggested for this purpose. A 1.5-inch-diameter (38 mm) hardwood handle provides a better grip than the steel-pipe handles. Reject hack-saw blades can be purchased locally and welded to cone-shaped transition sockets. Figure 8-1, for attaching the wooden handles to the blades.

8.2 STRAIGHTENING SEAL WEB

Severely bent seal webs are straightened with long crow bars, Figure 8-2. Generally this is mainly to put the seals in the correct horizontal position. A new tool to replace the crow bar has been developed, Figures 8-3, 8-4, 8-5. It provides a more positive grip that will not slip off. It also enables the millwright to bend the seal both up and down, thus eliminating the hammering operation, Figure 8-6, previously required to bend the seal down.

8.3 STRAIGHTENING SEAL-KNIFE EDGE

The next step is to remove the side-to-side waviness of the knife edges. To do this a tool is used to bend the knife edges inwards or outwards, Figures 8-7 and 8-8. The tool has a knob at the top of the handle for adjusting the grip on the knife edge.

8.4 CORNER GAGE BLOCKS

The corners of the door seal should be bent into position first. After the correct corner heights are established, an experienced millwright can usually straighten the remainder of the seal by eye. A magnetic gage block, Figures 8-9 and 8-10, enables the millwright to measure the corner height quickly.

8.5 WELDING AND GRINDING TORN SEALS

Nicks and tears are repaired by welding and grinding. High-speed pneumatic shaft grinders (Dunmore Model No. 47-100) have proven to be an effective tool for the grinding.

8.6 DETECTING SEAL OUT-OF-FLATNESS

Currently, the specification for knife-edge flatness is 5 mils per foot of depth (0.13 mm per 0.3 m). A quick and accurate method of detecting dips in the seal knife edge is needed. Measuring with a straightedge and a feeler gage is the direct way. Also, a two-grip file can be used for this purpose. The file, Figures 8-11, 8-12, has clamp-on grips at each end of a standard mill-bastard file. Out-of-flatness of the bearing surface of the seal knife edge is detected by pushing the file around the knife-edge bearing surface and watching for gaps in the shiny filed knife edge. The steel front grip provides the correct weight for this purpose.

8.7 HAND-FILING SEAL KNIFE EDGE

Hand-filing of the seal knife-edge surface is a critical and important step in seal repair. Ordinary files cannot be used by stroking parallel to the knife edge since the handle lifts one end of the file on a flat edge, Figure 8-13. Filing with perpendicular strokes does a poor job, often causing more out-of-flatness than it removes. Filing without the handle is hard on the hands and knuckles and a safety violation. The two-grip file, shown in Figure 8-12, resolves these problems. The tool is used for filing with pressure on both grips.

8.8 FINAL SPECIFICATIONS OF THE RECONDITIONED SEAL

Regardless of the amount of straightening and filing done to the seal and the methods that are used, the important matter is that the seal must meet the following final specifications.

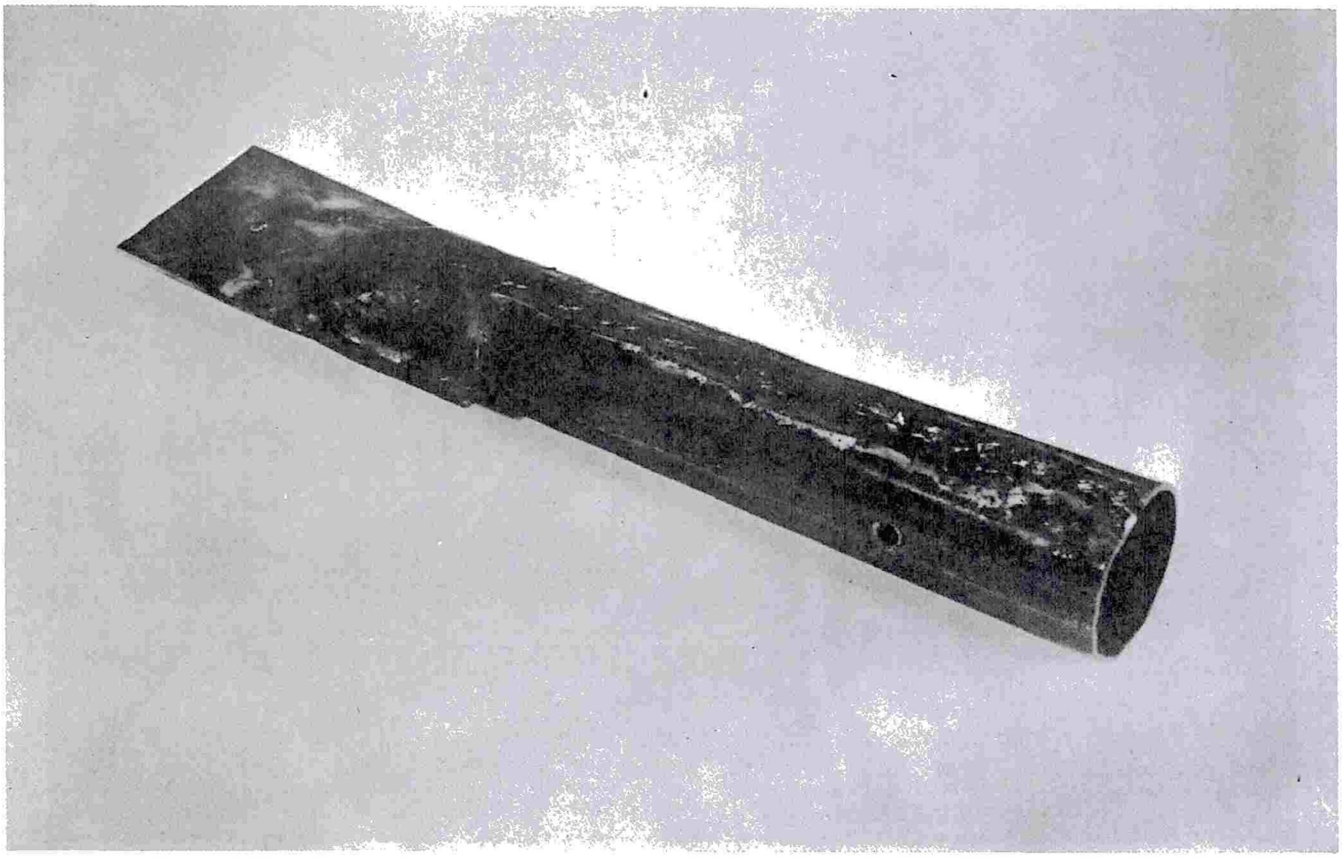
8.8.1 The seal waviness cannot exceed 1/8 inch (3 mm) over its entire length, Section 3.7.8.

8.8.2 The seal knife-edge flatness should not exceed 0.004 inch per foot around the entire perimeter of the seal, Section 3.7.9.

8.8.3 Each of the four corners of the seal knife edge must lie in the same plane, Section 3.7.10.

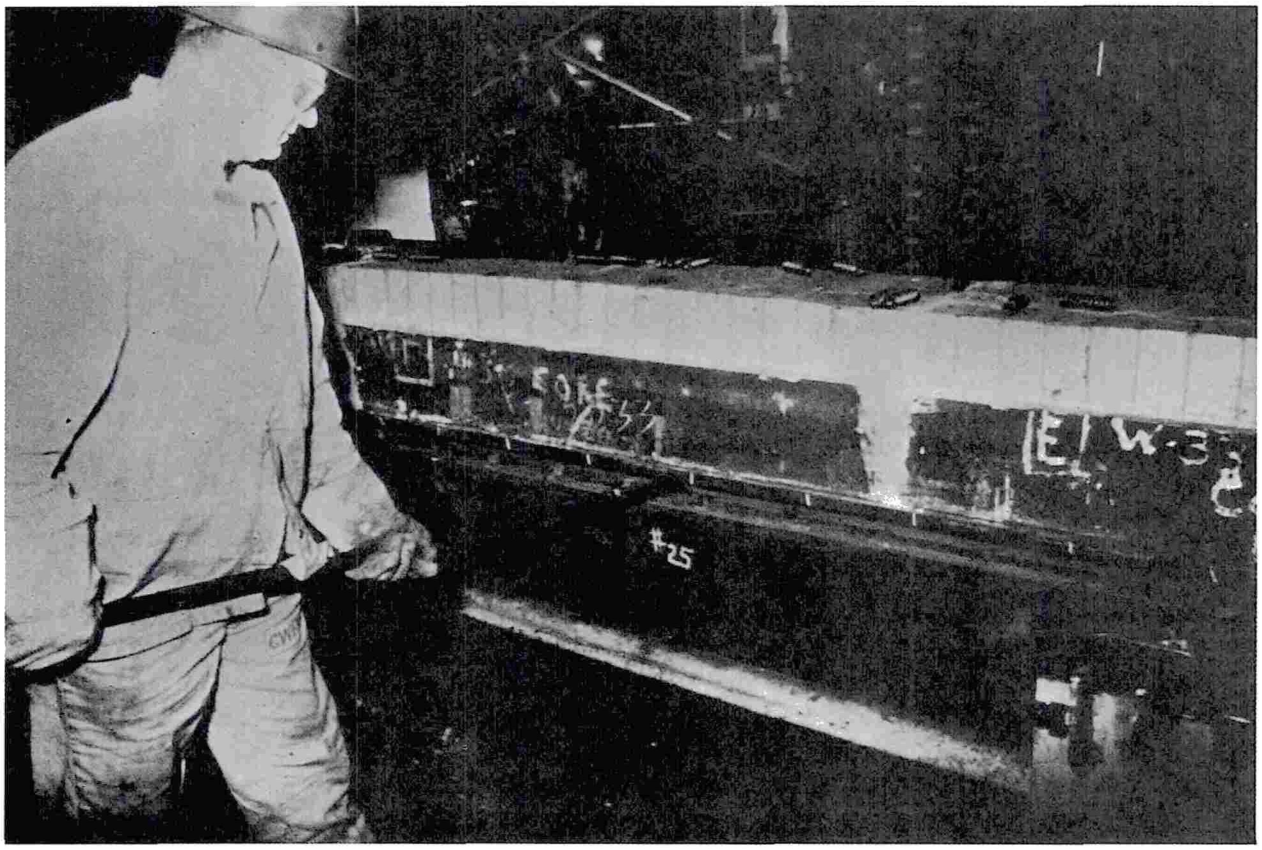
8.8.4 The knife edge of the seal should be 1/8-inch to 3/16 inch (3 to 5 mm) forward (towards the oven) of the four guide/stop blocks, Section 3.7.11.

8.8.5 There should be at least 3/16-inch (5 mm) clearance between the sides of the seal knife edge and the sides of the guide/stop blocks.



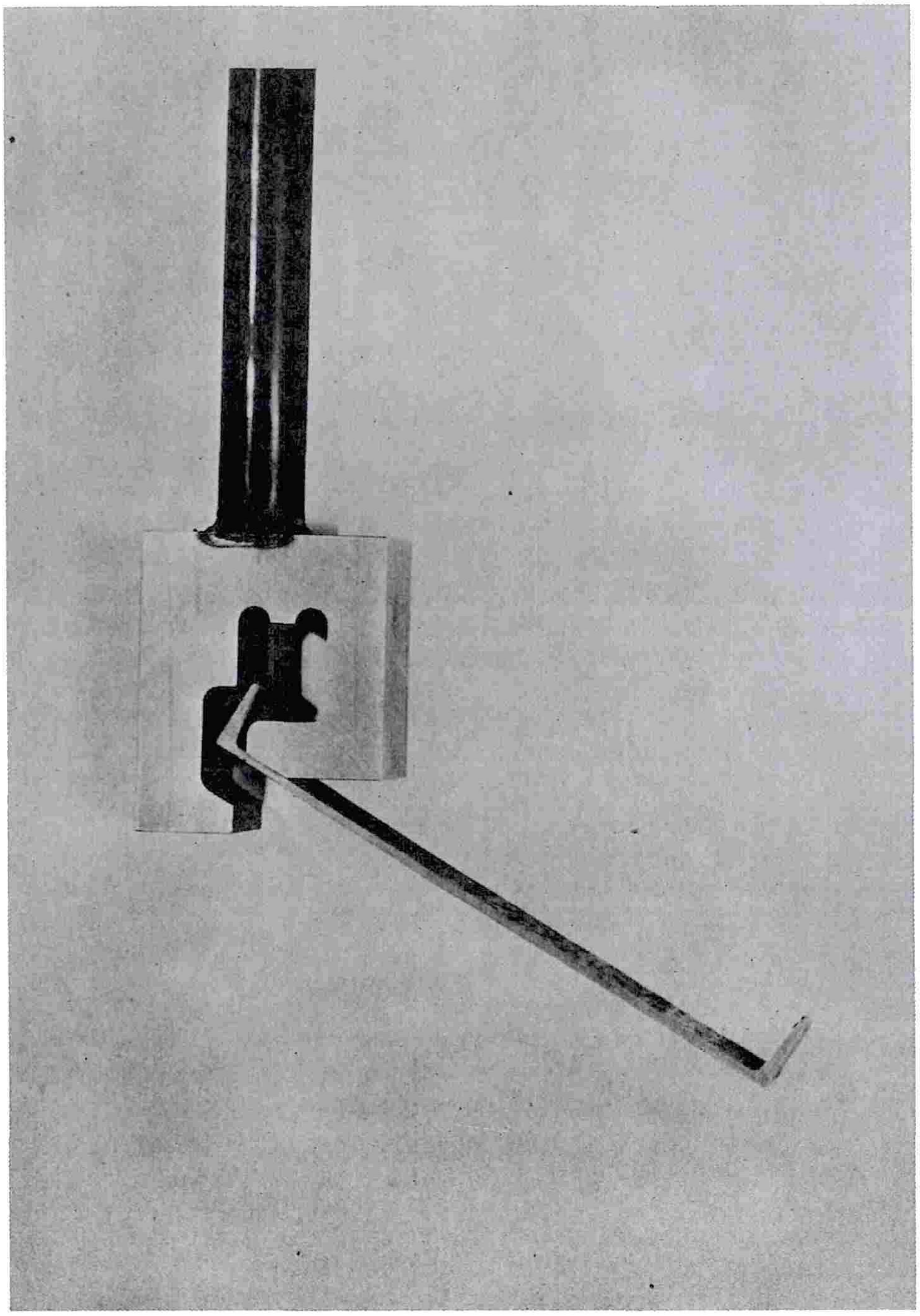
SOCKET FOR ATTACHING HARDENED STEEL BLADE TO WOODEN HANDLE. TOOL IS USED FOR CLEANING COKE-OVEN DOORS.

Figure 8-1



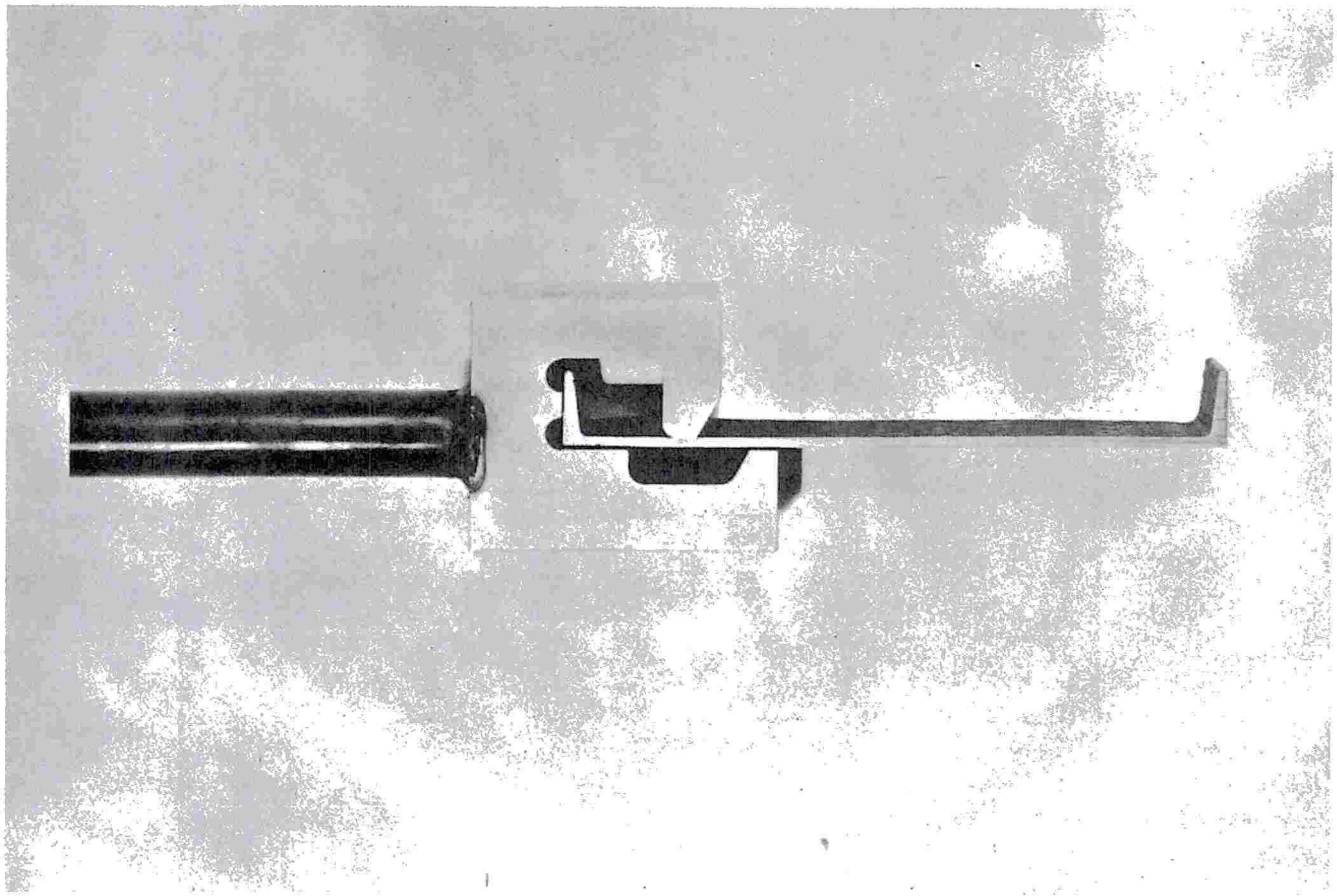
MILLWRIGHT BENDING COKE-OVEN-DOOR SEAL
UPWARDS WITH LONG CROW BAR

Figure 8-2



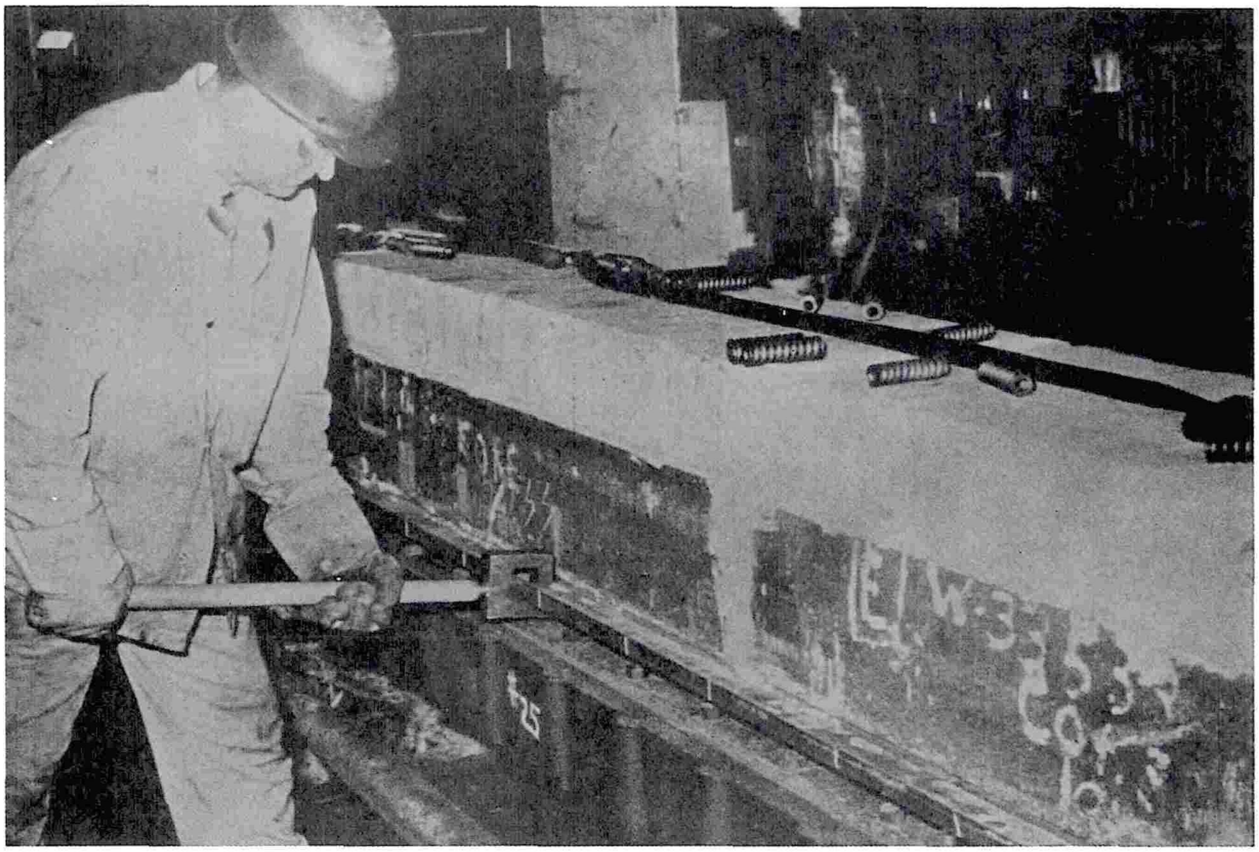
NEW BENDING TOOL BEING FITTED TO STEEL SHAPE USED FOR COKE-OVEN-DOOR SEALS

Figure 8-3



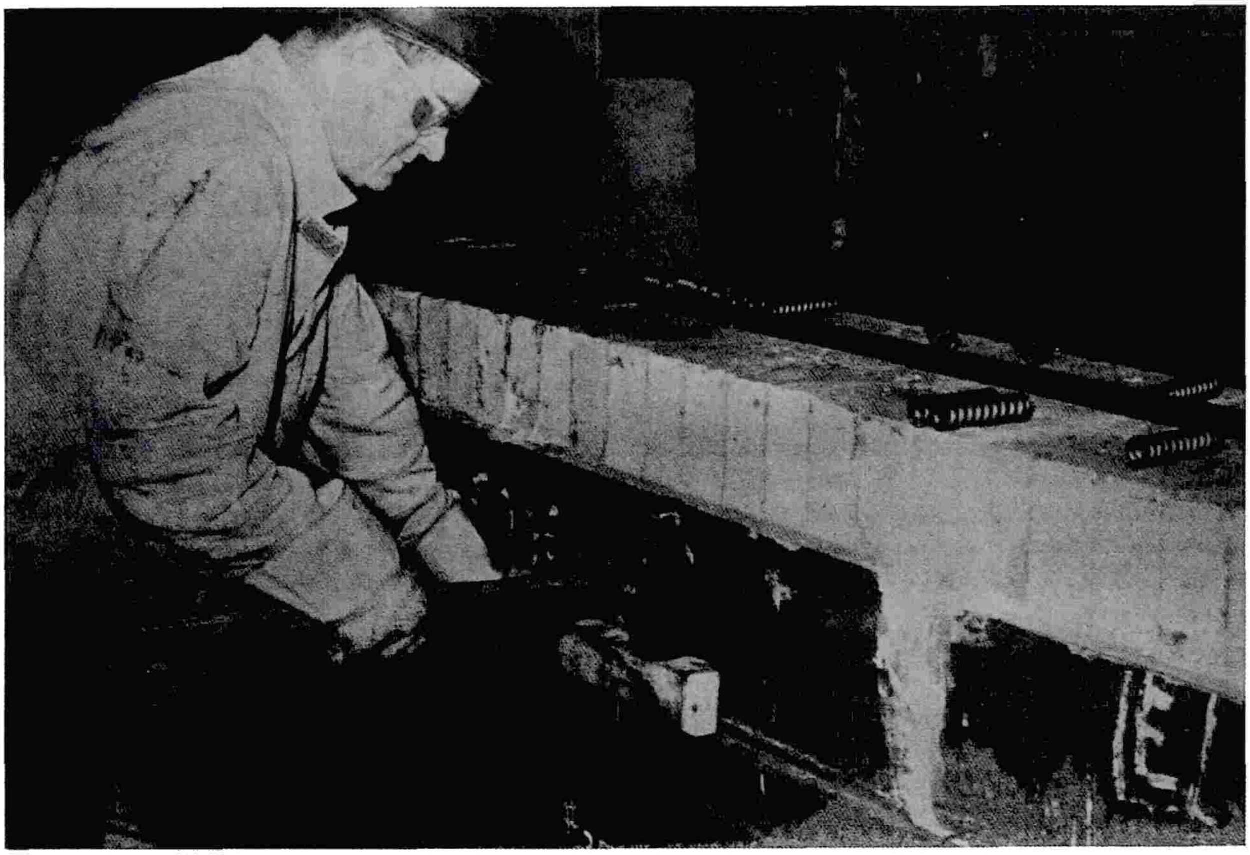
NEW TOOL SHOWN IN FIGURE 8-3 IN CORRECT
POSITION FOR BENDING COKE-OVEN-DOOR SEAL

Figure 8-4



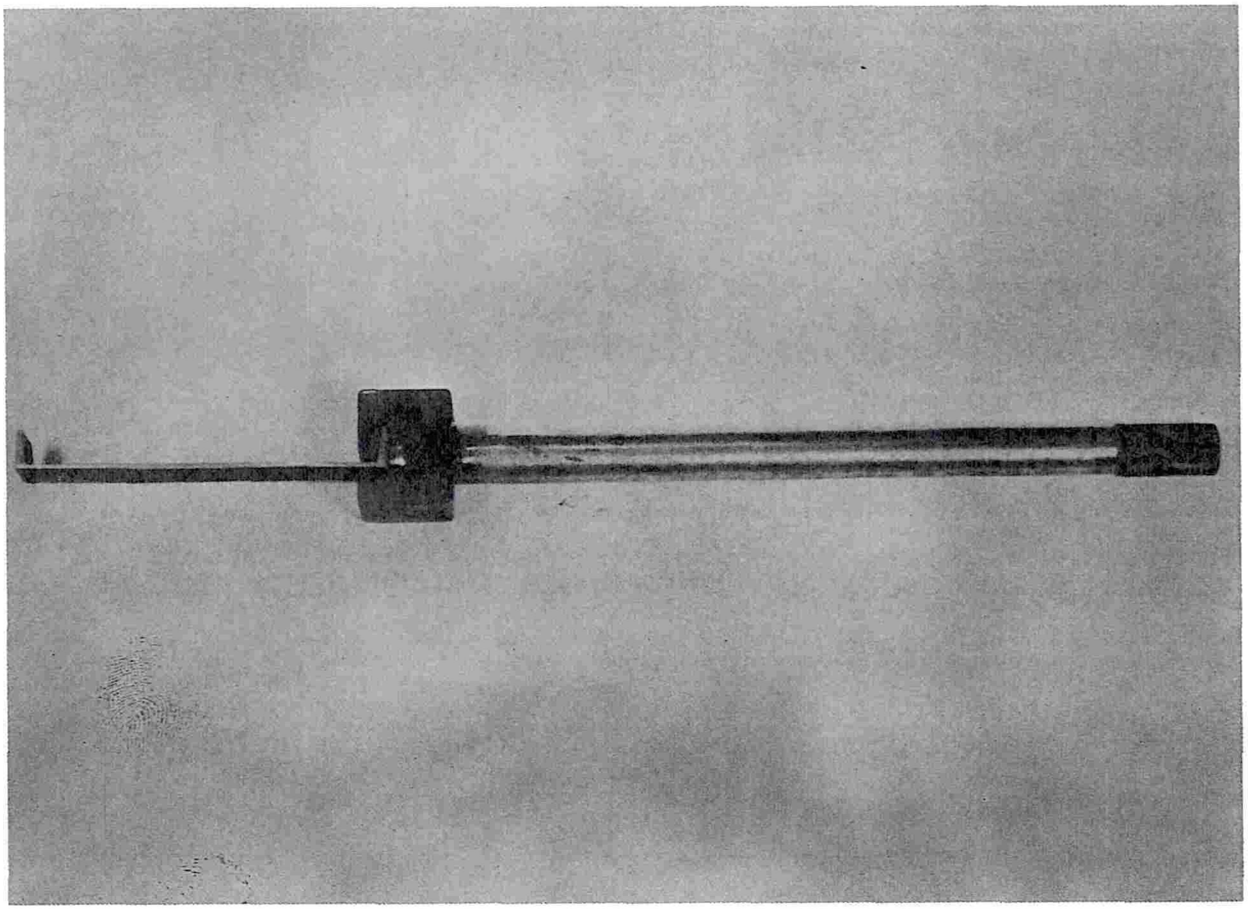
MILLWRIGHT USING NEW TOOL SHOWN IN FIGURES 8-3 AND 8-4
FOR BENDING COKE-OVEN-DOOR SEAL UP OR DOWN

Figure 8-5



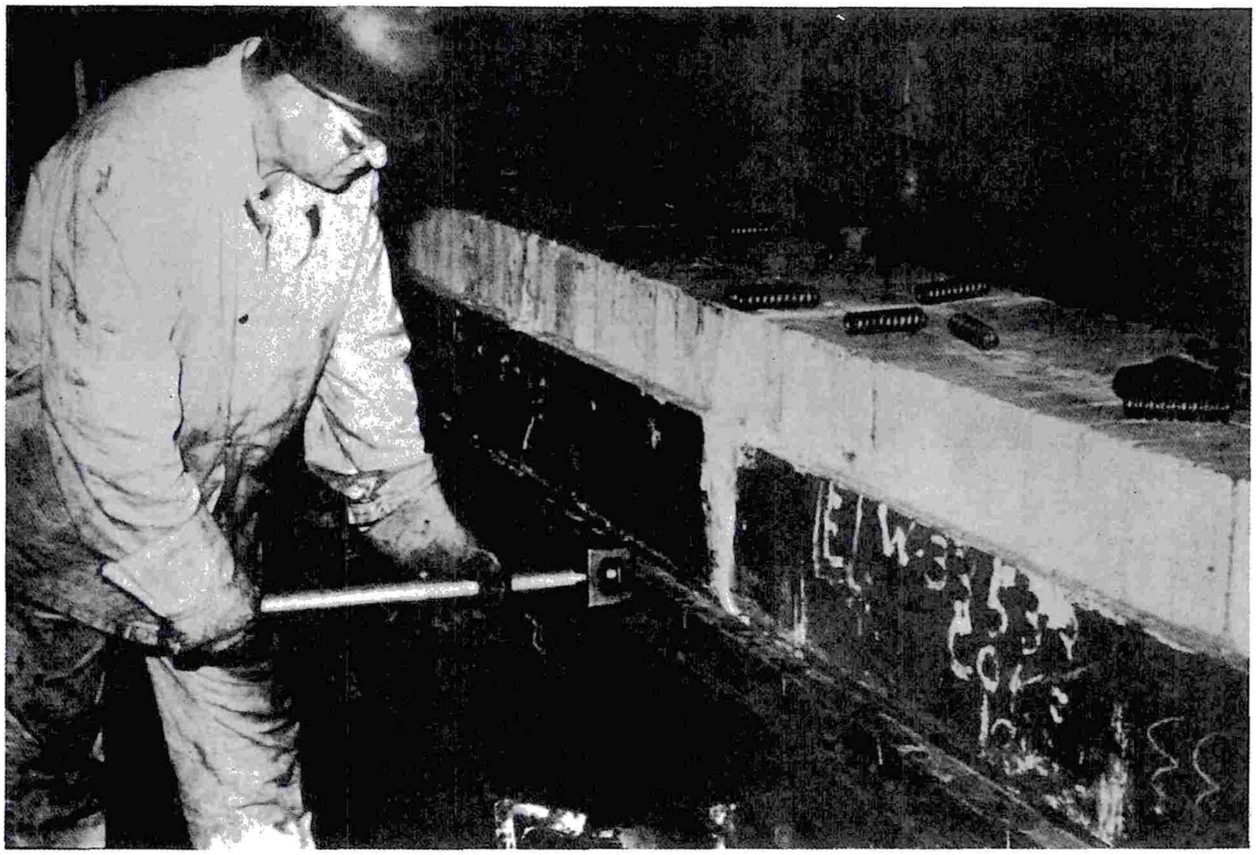
MILLWRIGHT HAMMERING COKE-OVEN-DOOR SEAL DOWNWARD.
WOODEN BLOCK PREVENTS DAMAGE TO SEAL KNIFE EDGE.

Figure 8-6



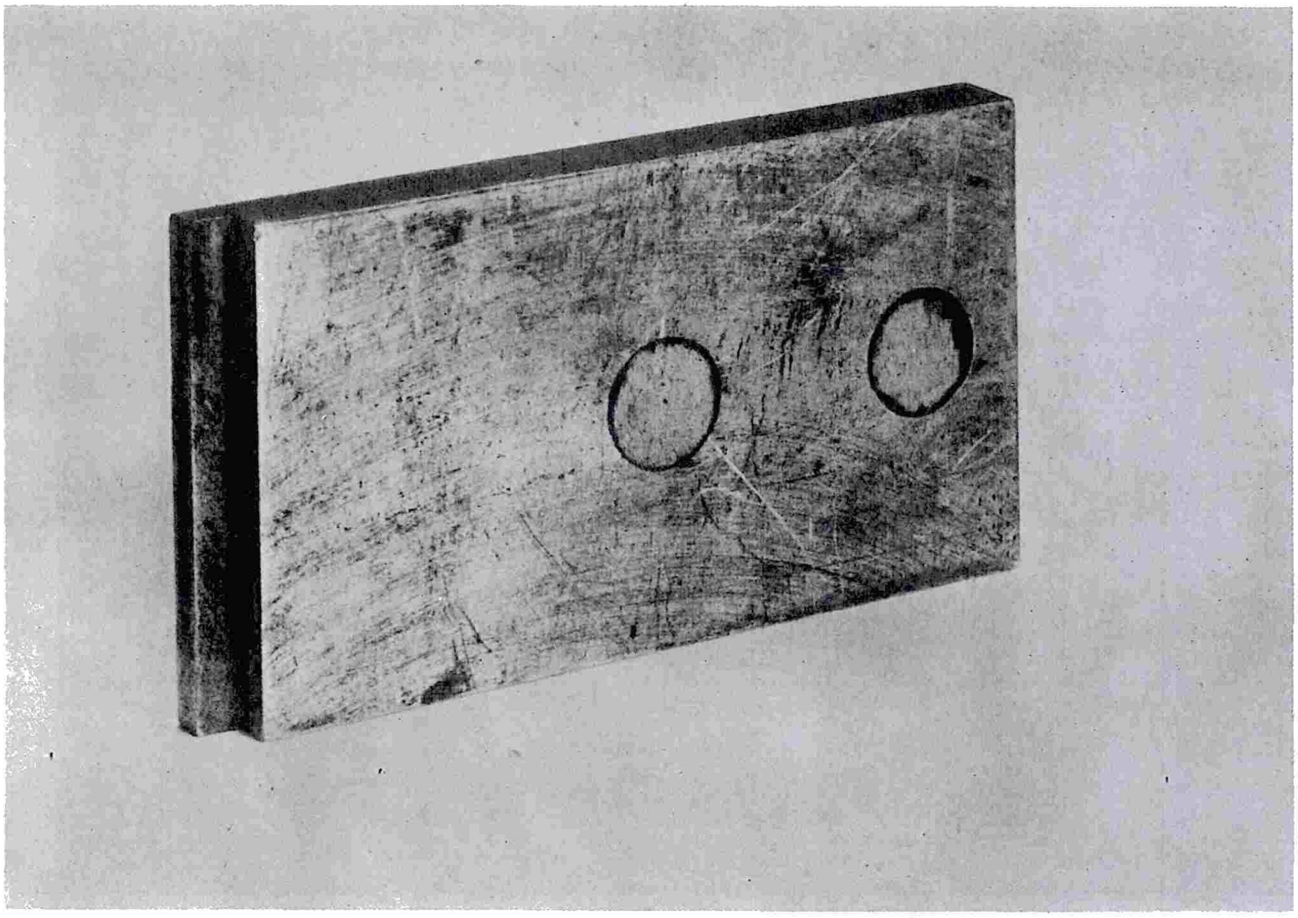
TOOL GRIPPING A SECTION OF STEEL USED FOR BENDING COKE-OVEN-DOOR SEAL KNIFE EDGE

Figure 8-7



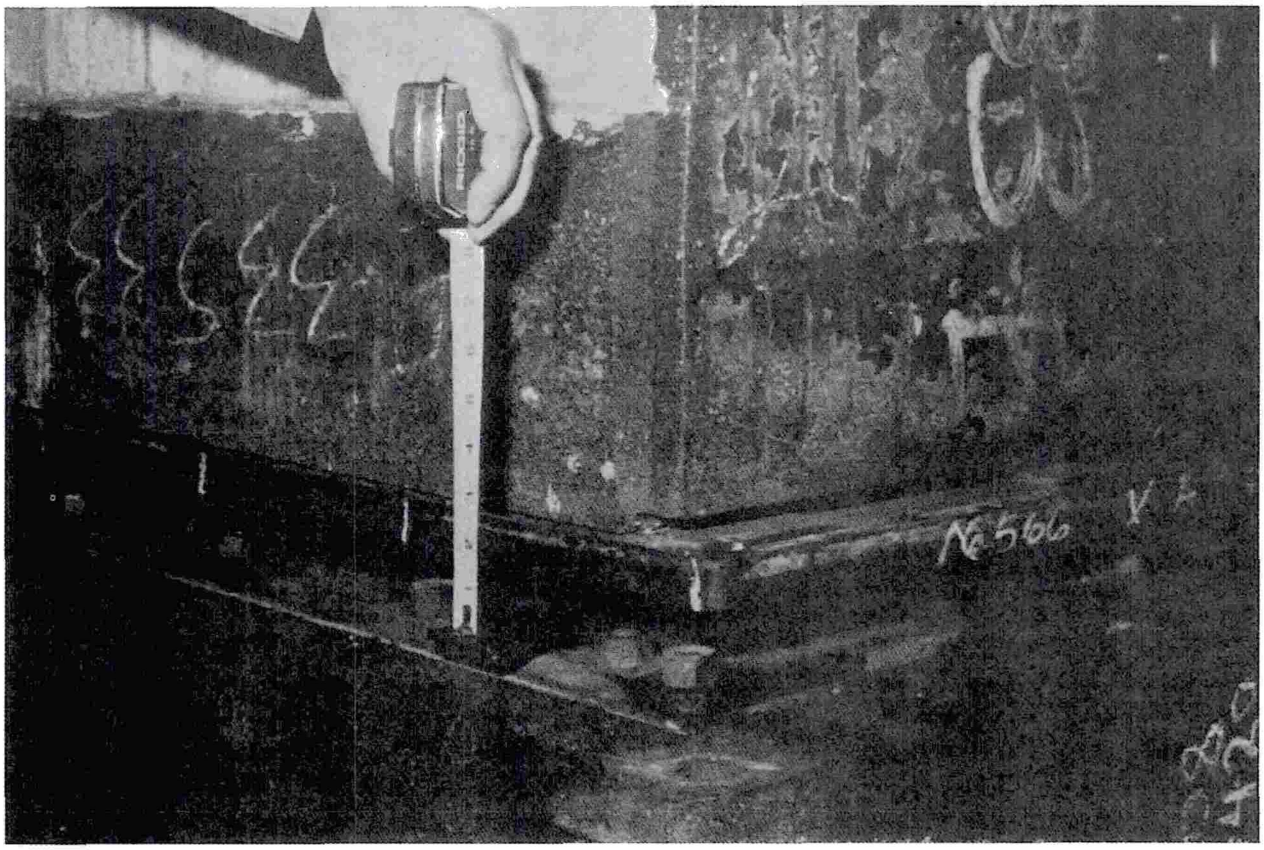
MILLWRIGHT USING TOOL IN FIGURE 8-7 FOR STRAIGHTENING KNIFE EDGE (BENDING TOWARDS OR AWAY FROM WORKMAN)

Figure 8-8



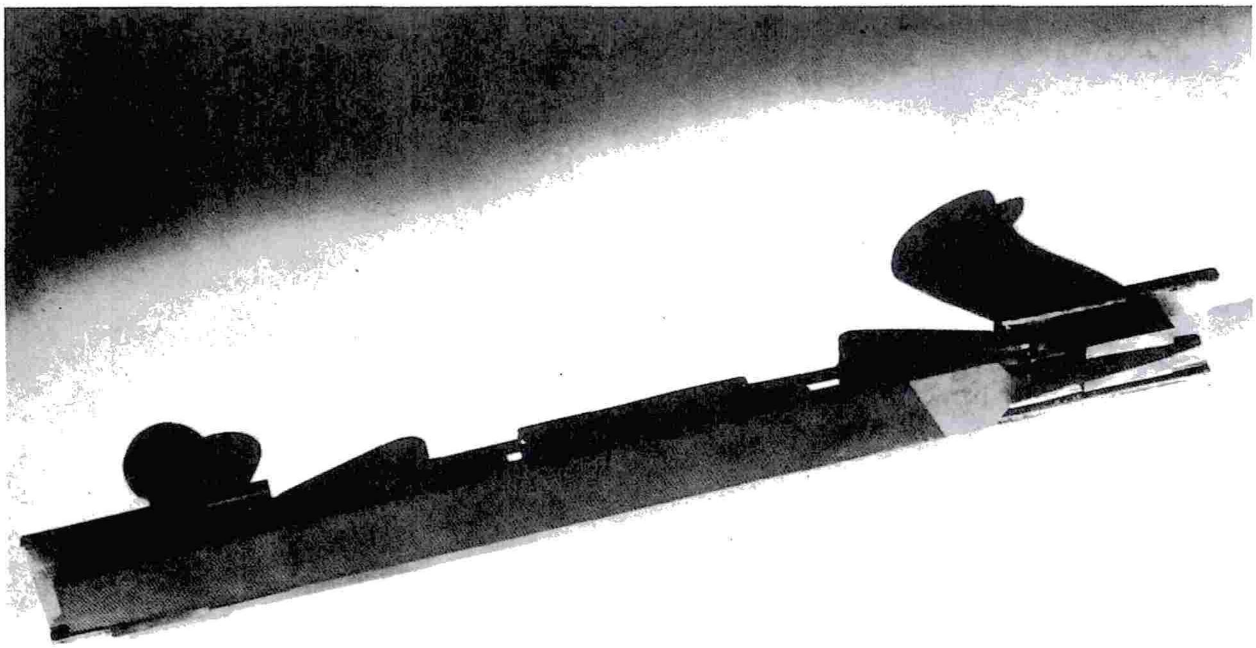
REFERENCE GAGE BLOCK WITH MAGNET INSERTS FOR USE IN MEASURING DISTANCE OF COKE-OVEN-DOOR KNIFE EDGES FROM DOOR FRAME

Figure 8-9



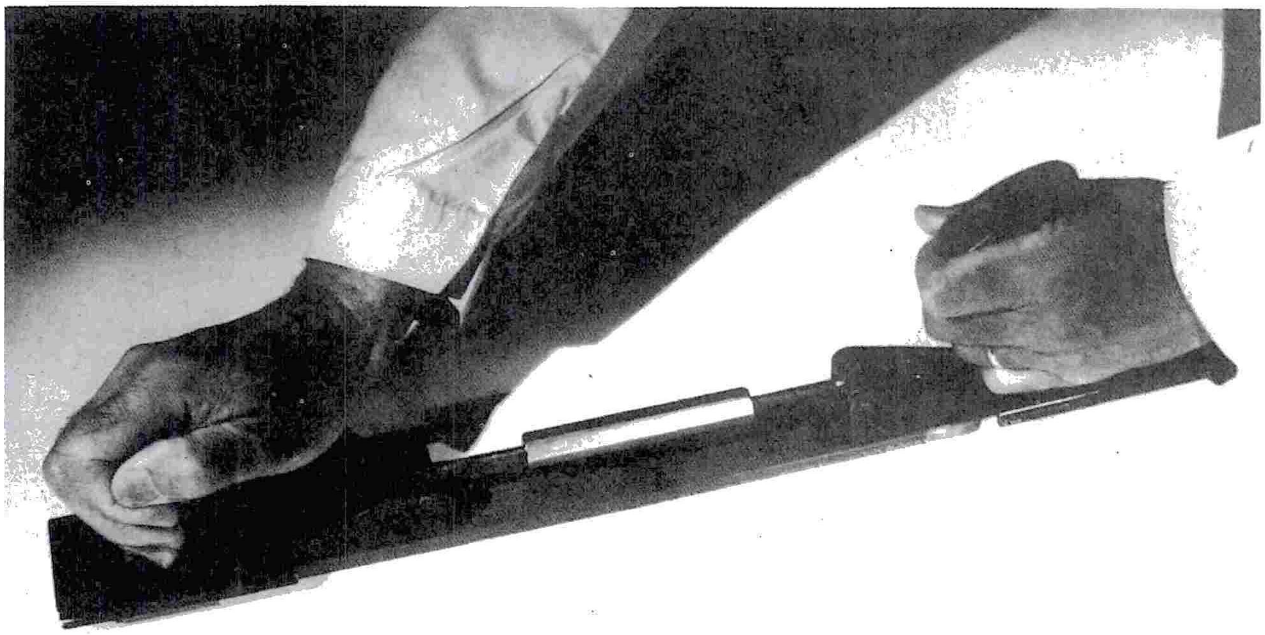
MILLWRIGHT USING GAGE BLOCK SHOWN IN FIGURE 8-9 TO ESTABLISH DISTANCE OF DOOR-SEAL CORNERS FROM DOOR FRAME

Figure 8-10



TWO-GRIP FILE FOR USE ON COKE-OVEN-DOOR SEALS

Figure 8-11



PROPER HAND POSITIONING OF FILE
SHOWN IN FIGURE 8-11

Figure 8-12

INCORRECT FILING OF COKE-OVEN-DOOR SEAL WITH STROKE ACROSS INSTEAD OF PARALLEL WITH THE KNIFE EDGE

Figure 8-13

Table of Contents—Section 3

Emission Control Techniques

Use of Refractory Materials to Control Topside Emissions (Coke Ovens)

LIQUID SEAL FOR CONTROL OF EMISSIONS FROM COKE-OVEN OFFTAKE SLIPJOINTS

1. INTRODUCTION

The large volumes of volatile products liberated in a coke oven during the coking of coal are conducted into the collector mains through an arrangement of offtake piping that includes an ascension pipe and elbow (gooseneck). On some battery designs the conventional arrangement is as shown in Figure 1, where the gooseneck is rigidly supported at one end from the collector main. The gooseneck also receives some support at the opposite end by the ascension pipe through a packed "slipjoint". Some flexibility in the joint is necessary to accomodate the relative movement between the coke oven, the offtake piping, and the collector main due to thermal cycling of the system.

For batteries having this type of design, the conventional method of sealing the slipjoint, as shown in Figure 1, consists of packing with high temperature rope and covering with a mortar slurry. However, this type of seal has proven to be unsatisfactory. As the mortar hardens, the joint becomes rigid and causes excessive forces to be transmitted to the collector mains and to the oven-top support for the ascension pipe. In addition, inherent cracks in the mortar often permit the escape of visible emissions to the atmosphere and necessitate frequent addition of new sealing slurry.

It should be noted that in another common offtake piping arrangement, the slipjoint is located in the collector main, rather than at the ascension pipe. Because this slipjoint is in a relatively low-temperature area, the sealing problem is much less severe. This discussion therefore is limited to those batteries having the slipjoint located at the ascension pipe.

2. IMPROVED SEAL DESIGN

U. S. Steel has developed an improved method for sealing the slipjoint between the ascension pipe and the gooseneck to prevent leaking from the offtake piping. To illustrate the concept, the design currently in use on the batteries at U. S. Steel's Geneva Works is shown in Figure 2. The dimensions are specific to the Geneva Works system and could vary for other batteries. The design basically consists of a continuous trough welded near the top of the ascension pipe and containing a liquid medium into which an extension welded to the bottom of the gooseneck is inserted to form the seal. A cover plate ring is installed above the trough for protection from rain and local dust. Numerous types of materials were tested, and rejected, as the sealing medium before the currently-used system was developed. These materials included water, diesel oil, polyglycol, and silicone foam. All of these were unsuitable due to high rate of replacement, fuming, or thermal degeneration. The requirements for an effective seal fluid is that it have a satisfactory service-temperature range, have a low viscosity-temperature slope, be nontoxic, be resistant to condensing out of liquids and tars from the gas stream, and be chemically inert to the trough construction material.

The most effective system to date employs a silicone fluid (dimethyl polysiloxane) as the liquid sealant. This material has a boiling point of approximately 725°F. Thermal decomposition begins to occur at about 660°F. The flash point is greater than 600°F. (The temperature of the outer surface of the ascension pipe has been measured in the range of 200-500°F). Two different manufacturers' products have been tested, Dow Corning 200-1000 cts. (centistokes), and Stauffer Chemical SWS 101-1000 cts. Both show similar satisfactory results.

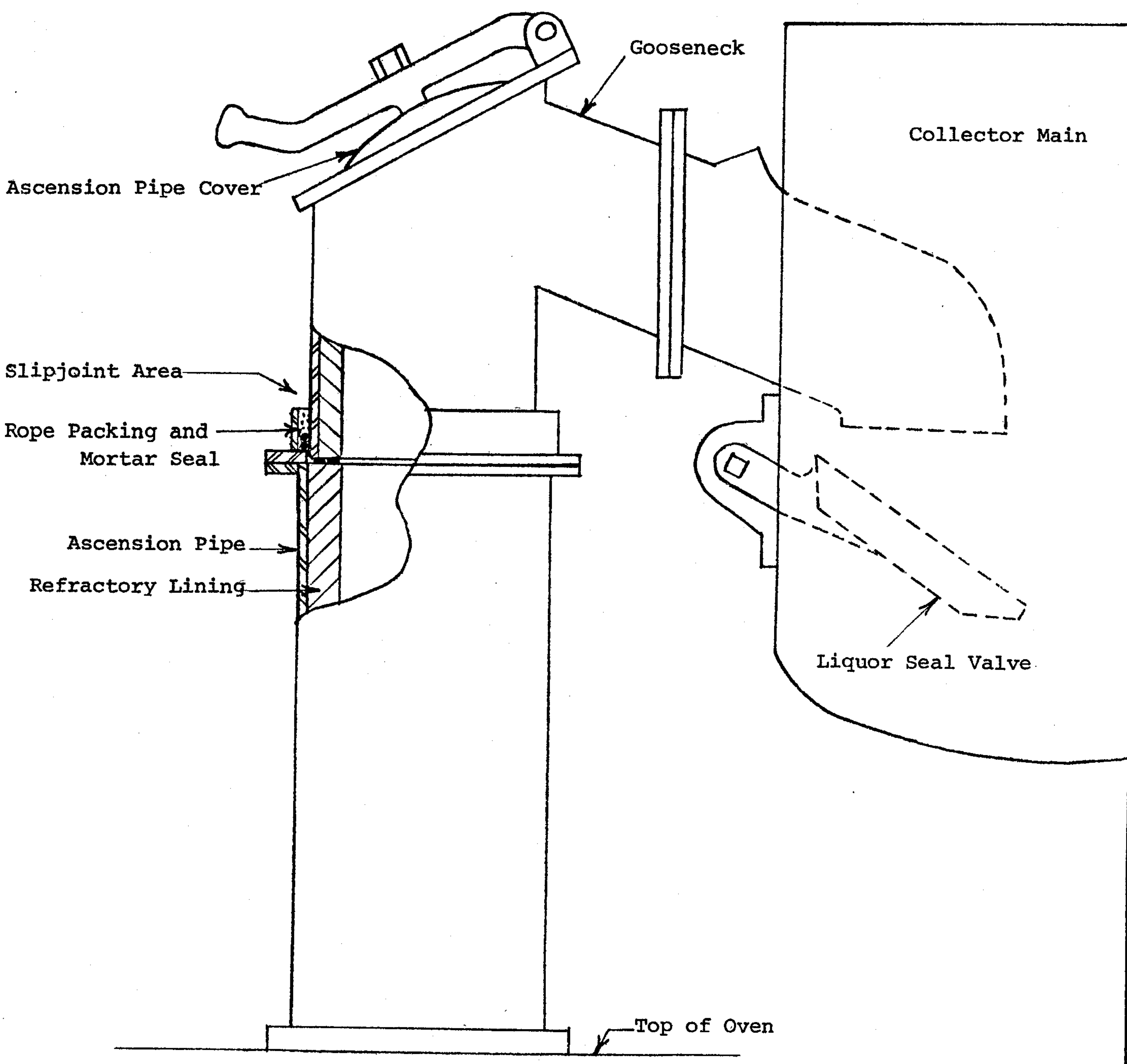
At Geneva Works, sand is used as a filler in the sealing trough to reduce the quantity of the expensive silicone fluid needed and to prevent the loss of fluid by excessive pressure differentials. The sand is effective for this purpose as it can withstand the temperature and does not degrade. At U. S. Steel's Clairton Works, a silicone-foam material has been employed for this purpose. The material used is Dow Corning Silicone Foam No. 3-6548, which is a room-temperature-vulconizing (RTV) elastomer. This material, which is commercially available as a standard product, comes in a two-part liquid. When the two parts are mixed in equal parts by volume, the material cures almost instantly in the hot trough to a sponge consistency four times its original liquid volume and characterized by an 85 percent closed cell structure with continuous service temperatures slightly above 500°F. After the trough is partially filled with the foam, a layer of the silicone fluid is added to complete the seal.

3. MAINTENANCE OF SEALS

At the Geneva Works, the slipjoint seals are inspected and any leakage noted twice daily, seven days per week, by coke plant employees and plant environmental observers. Fluid additions are then made to the slipjoint trough to eliminate visible leakage from any noted during the inspection. On the back turns, if the number of visible leaks from slipjoints approaches the established number of environmental limits, additional fluid will be added by a member of the battery crew, thereby providing 24-hour maintenance. When a joint begins to leak, about one or two gallons of new fluid is added. Records indicate that to maintain an environmentally sound sealing program, fluid additions to each joint are required on an average of about once in a 38-day period. The total addition of fluid has averaged 0.15 gallon per gooseneck per day.

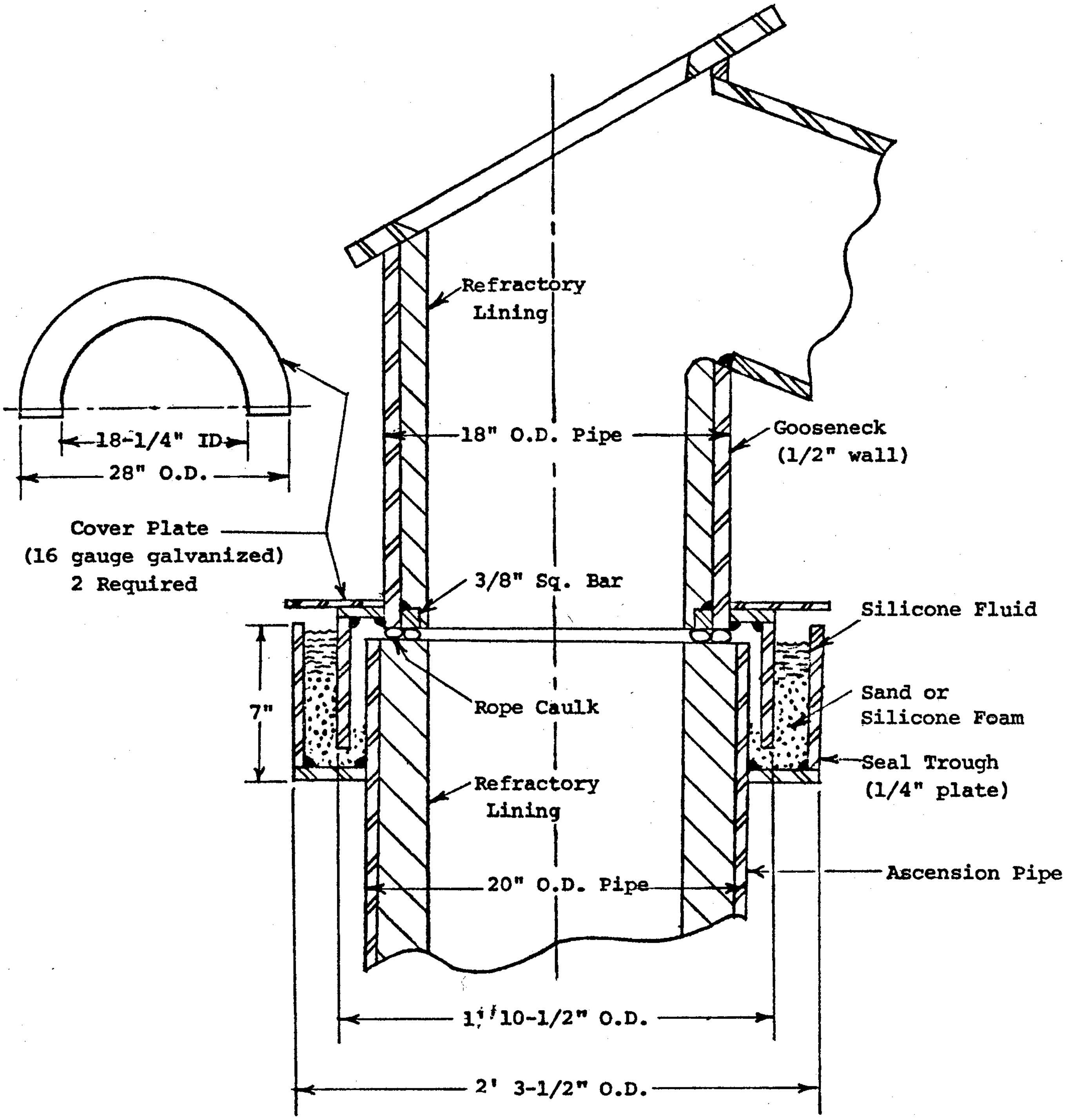
4. SUMMARY

A silicone-fluid seal for coke-oven offtake slipjoints has been developed, which successfully provides a positive gas seal to enable compliance with visible-emission regulations. The offtake assembly can expand and contract during the thermal cycle and still maintain the gas seal. Fluid consumption is minimized by combining the fluid with sand or silicone foam. The life of the gooseneck is extended by eliminating air infiltration at the slipjoint during the oven charging operation. A considerable savings in labor requirements is realized through elimination of the daily need to replenish the mortar seal in conventional slipjoints.



Conventional Offtake Piping with Slipjoint in Ascension Pipe

Figure 1



Liquid Seal for Slipjoint of Offtake Piping

Figure 2